OPERATING AND SERVICE MANUAL

HEWLETT PACKARD hp HARRISON DIVISION

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OPERATING AND SERVICE MANUAL

MODEL 865C

DC POWER SUPPLY

MANUFACTURING CODE 5E

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Table 1-1. Specifications

INPUT:	105-125/210-250 vac, 50 to 440 cps, single phase, 0.52 ampere, 47 watts max.
RATED OUTPUT:	Constant Voltage: 0 to 40 vdc Constant Current: 0 to 0.5 ampere dc
LINE REGULATION:	Constant Voltage: 0.01% plus 2 mv for 105-125/210-250 vac input change Constant Current: 0.02% plus 250 microamperes for 105-125/210-250 vac input change
LOAD REGULATION:	Constant Voltage: 0.01% plus 2 mv for 0 to 0.5 ampere load change Constant Current: 0.02% plus 250 microamperes for 0 to 40 volts load change
RIPPLE AND NOISE:	Constant Voltage: Less than 200 microvolts rms Constant Current: Less than 200 microamperes rms
OPERATING TEMPERATURE RANGE:	$0^{\circ}C$ to $50^{\circ}C$
TEMPERATURE COEFFICIENT:	Constant Voltage: 0.015% plus 1 mv per degree centigrade Constant Current: 0.02% plus 500 microamperes per degree centigrade
OUTPUT STABILITY: (after 30-minute warm-up)	Constant Voltage: 0.075% plus 5 mv for 8 hours at constant temperature Constant Current: 0.1% plus 1 milliampere for 8 hours at constant temperature
REMOTE PROGRAMMING:	Constant Voltage: 500 ohms per volt $\pm$1% Constant Current: 3000 ohms per ampere $\pm$10%

Table 1-1. Specifications (cont.)

HIGH SPEED VOLTAGE PROGRAMMING:

	No Load	Full Load
Rise Time: 0-40 vdc	30v/millisec	20v/millisec
Fall Time: 40-1 vdc	30v/millisec	40v/millisec
Fall Time: 1-0 vdc	0.5v/millisec	0.7v/millisec
Ripple and Noise	2 millivolts rms	2 millivolts rms

OUTPUT IMPEDANCE:

Less than 0.01 ohm from dc to 100 cps
Less than 0.02 ohm from 100 cps to 1 kc
Less than 0.5 ohm from 1 kc to 100 kc
Less than 3 ohms from 100 kc to 1 mc

OUTPUT INDUCTANCE:

0.16 microhenry

TRANSIENT RECOVERY TIME:

In constant voltage operation, less than 50 microseconds is required for output voltage recovery to within 10 millivolts of the nominal output voltage following a load change equal to the maximum current rating (0.5 ampere) of the power supply. Nominal output voltage is defined as the mean between the no-load and full-load voltages.

SIZE AND WEIGHT:

Height	Width	Depth	Weight
5-1/16 in.	7-13/16 in.	8-1/2 in.	12 lb.

FINISH:

Light gray front panel with dark gray wrinkle case.

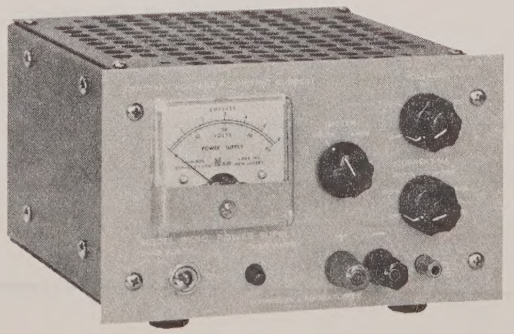


Figure 1-1. Model 865C DC Power Supply

SECTION I

GENERAL INFORMATION

1-1. DESCRIPTION

1-2. GENERAL

1-3. The H-Lab Model 865C DC Power Supply (fig. 1-1) is a completely transistorized, compact, well-regulated, constant voltage/constant current dc power supply suitable for either bench or relay rack operation. A three-wire five-foot input power cord is provided. The output is continuously variable between 0 and 40 vdc, and between 0 and 0.5 ampere. Detailed specifications are given in table 1-1.

1-4. OVERLOAD PROTECTION

1-5. A crossover feature protects both power supply and load in constant voltage operation. Automatic crossover circuitry switches the power supply from constant voltage to constant current operation if the output current exceeds a preset limit. This crossover circuitry also protects the load from overvoltage during constant current operation by automatically switching the power supply into constant voltage operation. The user can adjust the crossover point via the front panel controls (para. 3-1).

1-6. The power supply is protected from reverse voltage (positive voltage applied to negative terminal) by a diode that shunts current across the output terminals when this condition exists. Protection from reverse current (current forced into the power supply in the direction opposite to the output current) is provided by a diode that shunts reverse current across the series regulator.

1-7. COOLING

1-8. Convection cooling is used. No fan is required. The power supply has no moving parts (except for indicator of output monitoring meter).

1-9. MONITORING

1-10. A single meter and switch is provided for monitoring output voltage and current. The meter has a 0 to 40 volt range and a 0 to 0.6 ampere range with a 2% accuracy at full scale.

1-11. OUTPUT TERMINALS

1-12. Output power is available via five-way binding posts on the front panel and a terminal strip on the rear panel. The rear panel terminal strip also enables the power supply to be connected for different modes of operation (para. 3-3). The output terminals are isolated from the chassis and either the positive or the

negative terminal may be connected to the chassis via a separate ground terminal located adjacent to the output terminals. The power supply is insulated to permit operation up to 300 volts off ground.

1-13. ACCESSORIES

1-14. Table 1-2 lists accessories which are available.

Table 1-2. Accessories

Name	Part No.	Function
Rack Mounting, Single Unit	R855/865-1B	Permits a single power supply to be mounted in a 19 inch relay rack.
Rack Mounting, Dual Unit	R855/865-2B	Permits two power supplies to be mounted side-by-side in a 19 inch relay rack.
Case	C855/865	Improves appearance of power supply during bench use.

1-15. INSTRUMENT IDENTIFICATION

1-16. Harrison Laboratories power supplies are identified by a three-part designation. The first part is the model number; the second part is the serial number; and the third part is the manufacturing code letter. This manual applies to all Model 865C power supplies with the same manufacturing code letter given in the title page. Change sheets will be supplied with the manual to make it apply to Model 865C power supplies with different manufacturing code letters.

SECTION II

INSTALLATION

2-1. INITIAL INSPECTION

2-2. GENERAL

2-3. Before shipment, the power supply was inspected and found free of mechanical and electrical defects. If damage to the shipping carton is evident, ask that the carrier's agent be present when the power supply is unpacked. As soon as the power supply is unpacked, inspect it for any damage that may have occurred in transit. Also check the cushioning material for signs of severe stress (may be indication of internal damage). Save all packing materials until the inspection is completed. If damage is found, proceed as instructed in the Claim for Damage in Shipment notice on the back of the front cover of this manual.

2-4. MECHANICAL CHECK

2-5. Check that there are no broken knobs or connectors, that the external surface is not scratched or dented, that the meter face is not damaged, that all controls move freely, and that the fuse (at rear of power supply) is in place and of the correct rating (2 amperes, 250 volts). Any external damage may be an indication of internal damage.

2-6. ELECTRICAL CHECK

2-7. Check that the straps on the terminal strip at the rear of the power supply are secure and that the strapping pattern is in accord with figure 3-2A. Check the electrical performance of the power supply as soon as possible after receipt. A performance check that is suitable for incoming inspection is given in paragraphs 5-7 through 5-23.

2-8. INSTALLATION DATA

2-9. GENERAL

2-10. The power supply is shipped ready for bench operation. For operation in a standard 19 inch relay rack it is necessary to install a rack mounting. (Refer to paragraph 1-13.) For installing a single power supply or two power supplies side-by-side in a rack mounting, refer to paragraph 2-11.

2-11. RACK MOUNTING

2-12. To install the power supply in its rack mounting, proceed as follows:

a. Remove the top and bottom covers from the power supply by removing

both sets of four attaching screws.

b. Insert the power supply (rear end first) through the cutout in the rack mounting.

c. Replace the top and bottom covers inverted with respect to their original positions. The lip of each cover should be at the front end of the power supply and be going in the outward direction from the power supply. Use the original screws to secure the covers. The rack mounting should be held snugly between the back of the power supply front panel and the lips of the covers.

2-13. LOCATION

2-14. Because the power supply is cooled by convection, there must be enough space along the sides and rear of the power supply to permit free flow of cooling air. The power supply should be located in an area where the ambient temperature does not exceed 50°C.

2-15. POWER REQUIREMENTS

2-16. The power supply can be operated from either a 105 to 125 volt or 210 to 250 volt, 50 to 440 cps power source. The power supply is shipped from the factory wired for operation at 115 volts (nominal), unless otherwise ordered. At 115 volts, 60 cps, the full load requirement is 40.5 watts at 0.50 ampere.

2-17. 230-VOLT INPUT

2-18. To operate the power supply from a 230-volt power source, it is necessary to convert the primary windings of the input power transformer from parallel to series operation. (See figure 4-2.) Proceed as follows:

a. Remove top cover or case by removing attaching screws.

b. Remove the wire connecting terminals 1 and 1A and the wire connecting terminals 2 and 2A of the power transformer. Do not remove any other wires connected to these terminals. The terminal designations are stenciled in white on the transformer and are adjacent to their respective terminals.

c. Solder a wire between terminals 1A and 2.

d. Insert a 1 ampere, 250 volt fuse at rear of power supply. Replace the top cover or case.

2-19. POWER CABLE

2-20. To protect operating personnel, the National Electrical Manufacturers Association (NEMA) recommends that the instrument panel and cabinet be grounded. This instrument is equipped with a three-conductor power cable. The third

conductor is the ground conductor and when the cable is plugged into an appropriate receptacle, the instrument is grounded. The offset pin on the power cable three-prong connector is the ground connection.

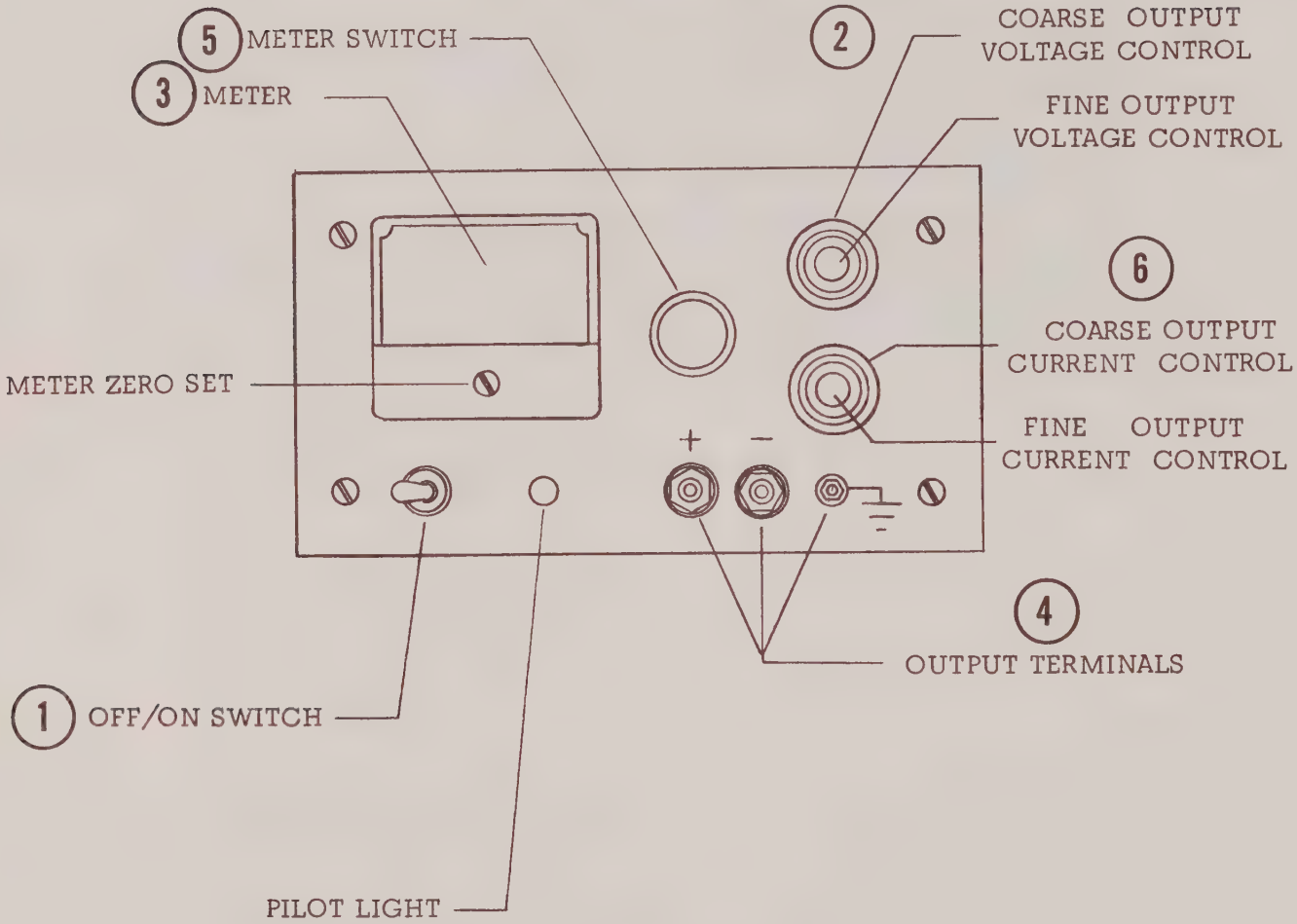
2-21. To preserve the protection feature when operating the instrument from a two-contact outlet, use a three-prong to two-prong adaptor and connect the green lead on the adaptor to ground.

2-22. REPACKAGING FOR SHIPMENT

2-23. To insure safe shipment of the instrument, it is recommended that the package designed for the instrument be used. The original packaging material is reusable. If it is not available, contact your Hewlett-Packard field office for packing materials and information. A packing carton part number is included in the parts list.

2-24. Attach a tag to the instrument which specifies the owner, model number, full serial number, and service required, or a brief description of the trouble.

SECTION III
OPERATING INSTRUCTIONS



1. TURN SUPPLY ON.
2. USE VOLTAGE CONTROLS TO SELECT OUTPUT VOLTAGE.
3. VOLTAGE IS INDICATED WHEN METER IS SWITCHED TO VOLTS.
4. SHORT CIRCUIT THE OUTPUT TERMINALS.
5. SWITCH METER TO AMPS TO READ CURRENT.
6. USE CURRENT CONTROLS TO ADJUST CONSTANT CURRENT LIMIT.
7. REMOVE SHORT AND CONNECT LOAD TO TERMINALS; NOTE: REAR TERMINALS MAY BE USED.

FIG. 3-1
FRONT PANEL CONTROLS & OPERATING PROCEDURE

SECTION III

OPERATING INSTRUCTIONS

3-1. CONTROLS AND INDICATORS

3-2. The controls and indicators are illustrated in figure 3-1.

3-3. OPERATION

3-4. GENERAL

3-5. The power supply is designed so that its mode of operation can be selected by making strapping connections between particular terminals on the terminal strip at the rear of the power supply. The terminal designations are stenciled in white on the power supply and are adjacent to their respective terminals. The strapping patterns illustrated in this section show neither terminal grounded. The operator can ground either terminal or operate the power supply up to 300 vdc off ground (floating).

3-6. NORMAL

3-7. GENERAL. The power supply is normally shipped with its rear terminal strapping connections arranged for constant voltage/constant current, local sensing, local programming, single unit mode of operation. This strapping pattern is illustrated in figure 3-2A. The operator selects either a constant voltage or a constant current output using the front panel controls (local programming, no strapping changes are necessary).

3-8. CONSTANT VOLTAGE. To select a constant voltage output, proceed as follows:

a. Turn-on power supply, set METER switch to VOLTS and adjust VOLTAGE control for desired output voltage (output terminals open).

b. Short output terminals, set METER switch to AMPS and adjust CURRENT control for maximum output current allowable (current limit), as determined by load conditions. If a load change causes the current limit to be exceeded, the power supply will automatically crossover to constant current output at the preset current limit and the output voltage will drop proportionately. In setting the current limit, allowance must be made for high peak currents which can cause unwanted cross-over. (Refer to paragraph 3-43.)

3-9. CONSTANT CURRENT. To select a constant current output, proceed as follows:

a. Short output terminals and set CURRENT control for desired output current.

b. Open output terminals and set VOLTAGE control for maximum output voltage allowable (voltage limit), as determined by load conditions. If a load change causes the voltage limit to be exceeded, the power supply will automatically crossover to constant voltage output at the preset voltage limit and the output current will drop proportionately. In setting the voltage limit, allowance must be made for high peak voltages which can cause unwanted crossover. (Refer to paragraph 3-43.)

3-10. CONNECTING LOAD

3-11. Output terminals are provided on the front panel and on the rear terminal strip of the power supply. Either pair of terminals or both may be used. The terminals are marked + and -. A separate ground terminal is located adjacent to each pair of output terminals. The positive or negative output terminal may be grounded, or neither grounded (floating operation; permitted to 300 volts off ground).

3-12. Each load should be connected to the power supply output terminals using separate pairs of connecting wires. This will minimize mutual coupling effects between loads and will retain full advantage of the low output impedance of the power supply. Each pair of connecting wires should be as short as possible and twisted or shielded to reduce noise pickup. (If shield is used, connect one end to power supply ground terminal and leave the other end unconnected.)

3-13. If load considerations require that the output power distribution terminals be remotely located from the power supply, then the power supply output terminals should be connected to the remote distribution terminals via a pair of twisted or shielded wires and each load separately connected to the remote distribution terminals. For this case, remote sensing should be used (para. 3-14).

NOTE

It is recommended that the voltage drop in the connecting wires not exceed 2 volts. If a larger drop must be tolerated, please consult a Hewlett-Packard field representative.

3-14. REMOTE SENSING

3-15. Remote sensing is used to ameliorate the degradation of regulation which will occur at the load when the voltage drop in the connecting wires is appreciable. The use of remote distribution terminals (para. 3-13) is an example where remote sensing may be required. Due to the voltage drop in the load leads, it may be necessary to slightly increase the current limit in constant voltage operation.

CAUTION

Turn-off power supply before rearranging strapping pattern at the power supply rear terminal strip. If -S terminal is opened while the power supply is on, the output voltage and current may exceed their maximum ratings and will result in damage to the load. If +S terminal is opened, the output voltage will exceed its maximum rating. The power supply will not be damaged.

3-16. Proceed as follows:

a. Turn-off power supply and arrange rear terminal strapping pattern as shown in figure 3-2E. The sensing wires will carry less than 10 ma and need not be as heavy as the load wires. It is recommended that sensing and load wires be twisted or shielded. (If shield is used, connect one end to power supply ground terminal and leave the other end unconnected.)

CAUTION

Observe polarity when connecting the sensing leads to the load.

b. In order to maintain low ac output impedance, a capacitor similar to C23 (see parts list) is connected across the load using short leads. This capacitor must have high-frequency characteristics as good or better than C23 has. Capacitor C23 is internally disconnected when the strap between + and A1 is removed. It may be necessary to adjust the transient recovery control to eliminate any tendency towards power supply oscillation (para. 4-24 and 5-78).

c. Turn-on power supply.

3-17. REMOTE PROGRAMMING

3-18. GENERAL. The constant voltage and constant current outputs may be programmed (controlled) from a remote location. The front panel controls are disabled in the following instructions. Changes in the rear terminal strapping arrangement are necessary. The wires connecting the programming terminals of the power supply to the remote programming device should be twisted or shielded to reduce noise pick-up. (If shield is used, connect one end to power supply ground terminal and leave the other end unconnected.) Remote sensing (para. 3-14) may be used simultaneously with remote programming. However, the strapping patterns shown in figures 3-2B, C, and D, employ only local sensing and do not show the load connections.

CAUTION

Turn-off power supply before rearranging strapping pattern at the power supply rear terminal strip. If voltage or current programming terminals are opened while power supply is on, the output voltage or current, respectively, will exceed its maximum rating and may result in damage to the load. The power supply will not be damaged. To protect the load from accidental opening of the remote programming terminals during operation, a zener diode may be placed directly across the power supply programming terminals. The zener diode rating should be equal to the maximum voltage that the load can safely take. For constant voltage programming, the positive terminal of the zener diode is connected to terminal +S and the negative terminal is connected to terminal A4. For constant current programming, the positive terminal of the zener diode is connected to terminal A6 and the negative terminal is connected to terminal A5.

3-19. CONSTANT VOLTAGE. In the constant voltage mode of operation, either a resistance or voltage source can be used for remote programming. For resistance programming, the programming coefficient (fixed by the programming current) is 500 ohms per volt (output voltage increases 1 volt for each 500 ohms in series with programming terminals). The programming current is adjusted to within 1% of 2 ma at the factory. If greater programming accuracy is required, change R15 (shunt). The programming resistance should be a stable, low noise, low-temperature (less than 30 ppm per ^{o}C) resistor with a power rating at least 10 times its actual dissipation.

3-20. The output voltage of the power supply should be 0 $\pm$20 mv when the programming resistance is zero ohms. This tolerance can be improved by changing R5. For further information on improving this tolerance, refer to paragraph 5-64 and to H-Lab Tech Letter #1.

3-21. If the resistance programming device is controlled by a switch, make-before-break contacts should be used in order to avoid momentary opening of the programming terminals. To connect the remote programming resistance, arrange rear terminal strapping pattern as shown in figure 3-2B. The front panel voltage control was disabled when the strap between A3 and A4 was removed. To reduce ripple, a 5-microfarad, 50-volt capacitor may be connected between the +S and A3 terminals as shown in the figure.

3-22 If a voltage source is used as the remote programming device, the output voltage of the power supply will vary in a 1 to 1 ratio with the programming

voltage. The load on the voltage source will not exceed 25 microamperes. The output impedance of the voltage source should be approximately 1000 ohms to maintain the temperature and stability specifications of the power supply. To connect the programming voltage, arrange rear terminal strapping pattern as shown in figure 3-2C. Resistor RX (shown in figure) is the output impedance (approximately 1000 ohms) of the programming voltage.

3-23. CONSTANT CURRENT. In constant current operation, resistance programming is used. The resistance programming coefficient (fixed by the programming current) is 3000 ohms per ampere (output current increases 1 ampere for each 3000 ohms in series with programming terminals). The programming current is adjusted to within approximately 10% of 1 ma at the factory. If greater programming accuracy is required, change R31 (shunt). The programming resistance should be a stable, low noise, low-temperature (less than 30 ppm per ^{o}C) resistor with a power rating at least 10 times its actual dissipation.

3-24. The output current of the power supply should be 0 $\pm$250μa when the programming resistance is zero ohms. This tolerance can be improved by changing R25. For further information on improving this tolerance, refer to paragraph 5-68 and to H-Lab Tech Letter #1.

3-25. If the resistance programming device is controlled by a switch, make-before-break contacts should be used to avoid momentary opening of the programming terminals. To connect the remote programming resistance, arrange rear terminal strapping as shown in figure 3-2D. The front panel current control is disabled when the strap between A6 and A7 is removed.

3-26. HIGH-SPEED PROGRAMMING

3-27. Due to the large output capacitance of the power supply (required for low ac output impedance) the output voltage cannot change as rapidly as the output current can in response to programming or load changes. For applications where output voltage response time is of primary importance, the output capacitance can be reduced by removing the strap between terminals + and A1 (see figures 3-2F and G). Figure 3-2F shows an example of a high-speed application. An externally energized relay closes the contact shown in the figure, reducing the programming resistance to near zero. The power supply output will fall to zero more rapidly with the + to A1 strap removed.

3-28. DC POWER AMPLIFIER

3-29. Using the rear terminal arrangement shown in figure 3-2H, the power supply can be used as a dc power amplifier with a variable voltage gain ($G=R_a/R_b$). High-speed remote programming (para. 3-17) is necessary. The useful frequency range is from dc to 1 kc. The output cannot go through zero (single ended). The input impedance is equal to R_b. Peak output power of 20 watts with less than 0.01% distortion from dc to 1 kc is obtainable. Resistors R_a and R_b should be stable,

low-noise, low-temperature (less than 30 ppm per ^{o}C) resistors with power ratings at least 10 times their actual dissipation. Remote sensing may be employed; however, local sensing is shown in the figure and load connections are not shown.

3-30. PARALLEL

3-31. GENERAL. Two or more power supplies can be connected in parallel to obtain a total output current greater than that available from one power supply. The total output current is the sum of the output currents of the individual power supplies. Each power supply can be turned-on or off separately. Remote sensing (para. 3-14) and programming (para. 3-17) can be used; however, the strapping patterns shown in figure 3-5 employ only local sensing and programming.

3-32. NORMAL. The strapping pattern for normal parallel operation of two power supplies is shown in figure 3-5A. The output current control of each power supply can be separately set. The output voltage control of one power supply (master) should be set to the desired output voltage; the other power supply (slave) should be set for a slightly larger output voltage. The master will act as a constant voltage source; the slave will act as a constant current source, dropping its output voltage to equal the master's.

3-33. AUTO-PARALLEL. The strapping patterns for auto-parallel operation of two and three power supplies are shown in figures 3-5B and C, respectively. Auto-parallel operation permits equal current sharing under all load conditions, and allows complete control of output current from one master power supply. The output current of each slave is approximately equal to the master's. Because the output current control of each slave is operative, they should be set to maximum to avoid having a slave revert to constant current operation; this would occur if the master output current setting exceeded the slave's.

3-34. SERIES

3-35. GENERAL. Two or more power supplies can be connected in series to obtain a total output voltage higher than that available from one power supply. The total output voltage is the sum of the output voltages of the individual power supplies. A single load can be connected across the series-connected power supplies or a separate load can be connected across each power supply. The power supply has a reverse polarity diode connected internally across the output terminals to protect the power supply against reverse polarity voltage if the load is short-circuited or if one power supply is turned off while its series partners are on.

3-36. The output current control of each power supply is operative and the current limit is equal to the lowest control setting. If any output current control is set too low with respect to the total output voltage, the series power supplies will automatically crossover to constant current operation and the output voltage will drop. Remote sensing (para. 3-14) and programming (para. 3-17) can be used; however, the strapping patterns shown in figure 3-3 employ only local sensing and programming.

3-37. NORMAL. The strapping pattern for normal series operation of two power supplies is shown in figure 3-3A. The output voltage control of each power supply must be adjusted to obtain the total output voltage.

3-38. AUTO-SERIES. The strapping patterns for auto-series operation of two and three power supplies are shown in figures 3-3B and C, respectively. Auto-series operation permits control of the output voltage of several power supplies (slaves) from one master power supply. The master must be the most negative power supply of the series. To obtain positive and negative voltages, the + terminal of the master may be grounded. For a given position of the slave output voltage controls, the total output voltage is determined by the master output voltage control. The output voltage control of a slave determines the percentage of the total output voltage that the slave will contribute. Turn-on and turn-off of the series is controlled by the master. In order to maintain the temperature coefficient and stability specifications of the power supply, the external resistors shown in figures 3-3B and C, should be stable, low-noise, low-temperature (less than 30 ppm per ^{o}C) resistors. These values are E_{out} of slave multiplied by programming coefficient.

3-39. AUTO-TRACKING

3-40. The strapping patterns for auto-tracking operation of two and three power supplies are shown in figures 3-4A and B, respectively. Automatic tracking operation permits the output voltages of two or more power supplies to be referenced to a common bus; one of the power supplies (master) controls the magnitude of the output voltage of the others (slaves) for a given position of the slave output voltage control. The master must be the most negative power supply in the group. The output voltage of a slave is a percentage of the master output voltage. The output voltage control of a slave determines this percentage. Turn-on and turn-off of the power supplies is controlled by the master. Remote sensing (para. 3-14) and programming (para. 3-17) can be used; however, the strapping patterns shown in figure 3-4 employ only local sensing and programming.

3-41. The value of the external resistors shown in figure 3-4 is determined by dividing the voltage difference between the master and the applicable slave by the programming current (nominally 2 ma; refer to para. 3-19). Finer adjustment of the slave output voltage can be accomplished using the slave output voltage control. In order to maintain the temperature coefficient and stability specifications of the power supply, the external resistors should be stable, low-noise, low-temperature (less than 30 ppm per ^{o}C) resistors.

3-42. OPERATING CONSIDERATIONS

3-43. PULSE LOADING

3-44. The power supply will automatically cross over from constant voltage to constant current operation, or the reverse, in response to an increase (over the preset limit) in the output current or voltage, respectively. Although the preset limit may be set higher than the average output current or voltage, high peak

currents or voltages (as occur in pulse loading) may exceed the preset limit and cause crossover to occur. To avoid this unwanted crossover, the preset limit must be set for the peak requirement and not the average.

3-45. OUTPUT CAPACITANCE

3-46. There are capacitors (internal) across the output terminals of the power supply. These capacitors help to supply high-current pulsesof short duration during constant voltage operation. Any capacitance added externally will improve the pulse current capability, but will decrease the safety provided by the constant current circuit. A high-current pulse may damage load components before the average output current is large enough to cause the constant current circuit to operate.

3-47. The effects of the output capacitors during constant current operation are as follows:

a. The output impedance of the power supply decreases with increasing frequency.

b. The rise time of the output voltage is increased.

c. A large surge current causing a high power dissipation in the load occurs when the load impedance is reduced rapidly.

3-48. NEGATIVE VOLTAGE LOADING

3-49. A diode is connected across the output terminals. Under normal operating conditions, the diode is reverse biased (anode connected to negative terminal). If a negative voltage is applied to the output terminals (positive voltage applied to negative terminal), the diode will conduct, shunting current across the output terminals and limiting the voltage to the forward voltage drop of the diode. This diode protects the series regulator transistors and the output electrolytic capacitors.

3-50. NEGATIVE CURRENT LOADING

3-51. Certain types of loads may cause current to flow into the power supply in the direction opposite to the output current. A diode is connected across the series regulator to shunt this reverse current. Under normal operation, the diode is reverse biased.

3-52. If the reverse current exceeds 45 milliamperes, preloading will be necessary. For example; if the load delivers 50 milliamperes to the power supply with the power supply output voltage at 40 VDC, a resistor equal to 800 ohms ($40/50 \times 10^{-3}$) should be connected across the output terminals. Thus, the 800 ohm resistor shunts the reverse current across the power supply. For more information on preloading, refer to paragraph C4 in the H-Lab Application Manual.

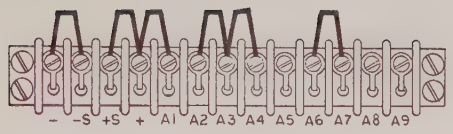


FIG. 3-2A
NORMAL

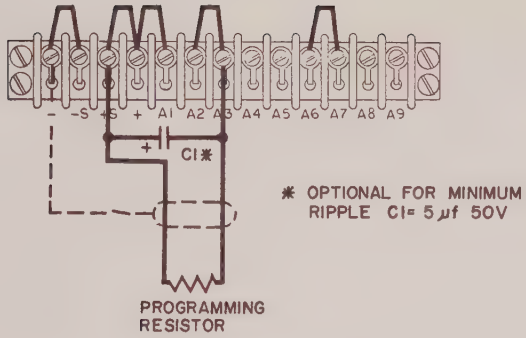


FIG. 3-2B
REMOTE PROGRAMMING CONSTANT VOLTAGE

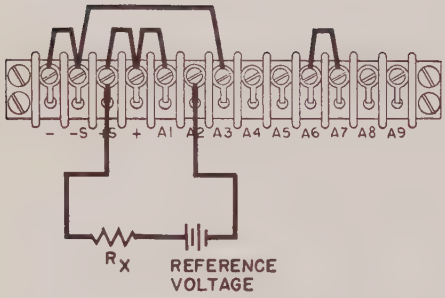


FIG. 3-2C
REMOTE PROGRAMMING VOLTAGE PROGRAMMING

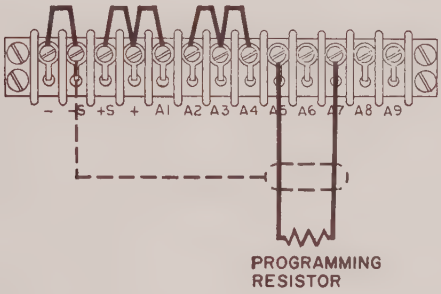


FIG. 3-2D
REMOTE PROGRAMMING
RESISTANCE PROGRAMMING FOR CONSTANT CURRENT

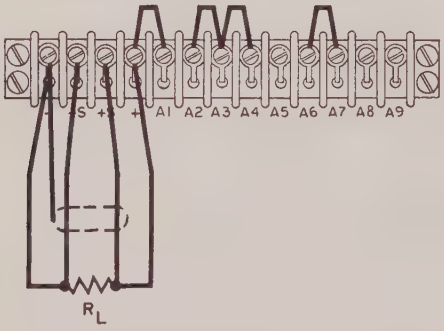


FIG. 3-2E
REMOTE SENSING

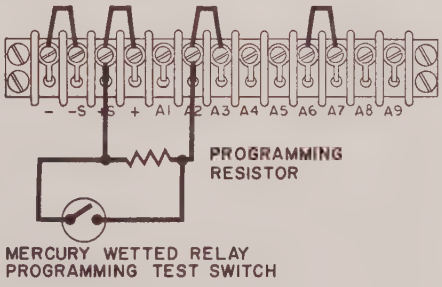


FIG. 3-2F
HIGH SPEED VOLTAGE PROGRAMMING
RESISTANCE PROGRAMMING

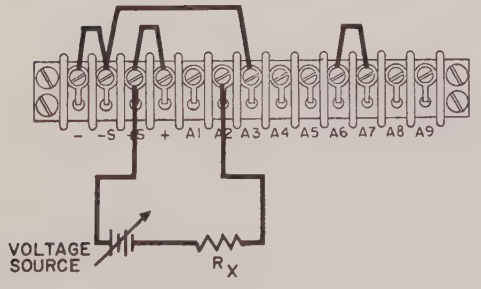


FIG. 3-2G
HIGH SPEED PROGRAMMING
VOLTAGE PROGRAMMING

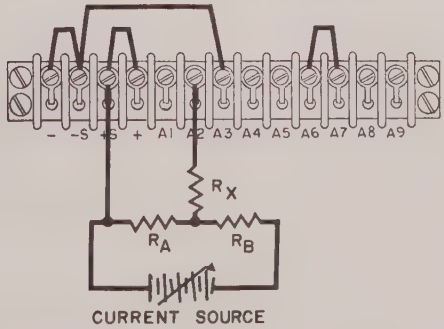


FIG. 3-2H
HIGH SPEED PROGRAMMING
CURRENT PROGRAMMING

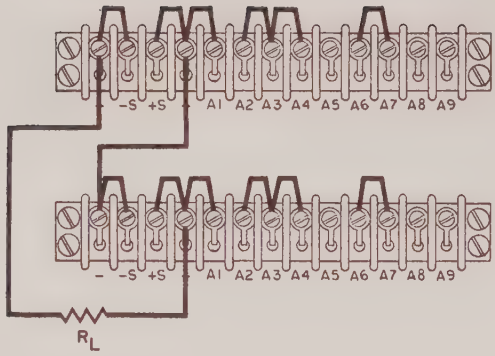
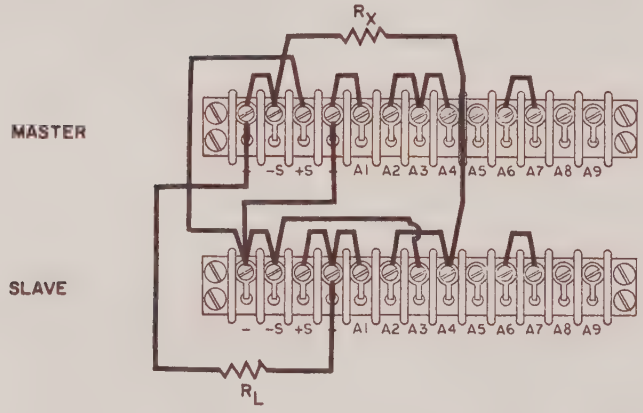
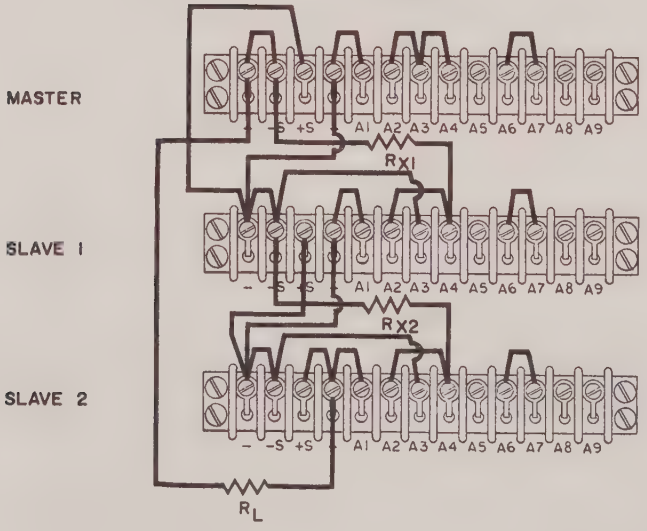


FIG. 3-3A
NORMAL SERIES OPERATION



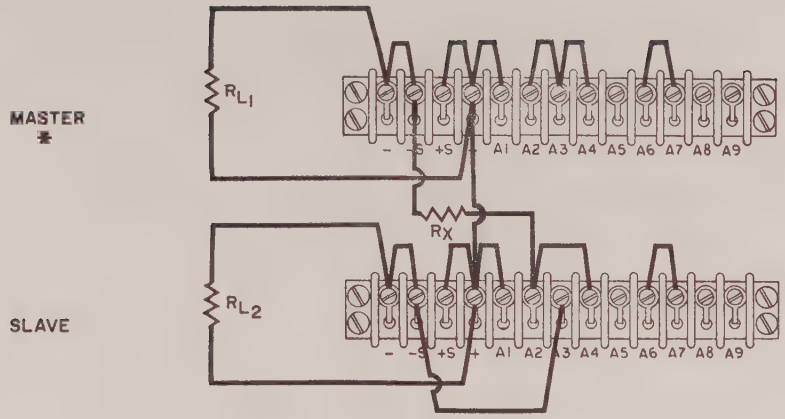
R_X = 20K

FIG. 3-3B
AUTO SERIES OPERATION
(TWO UNITS)



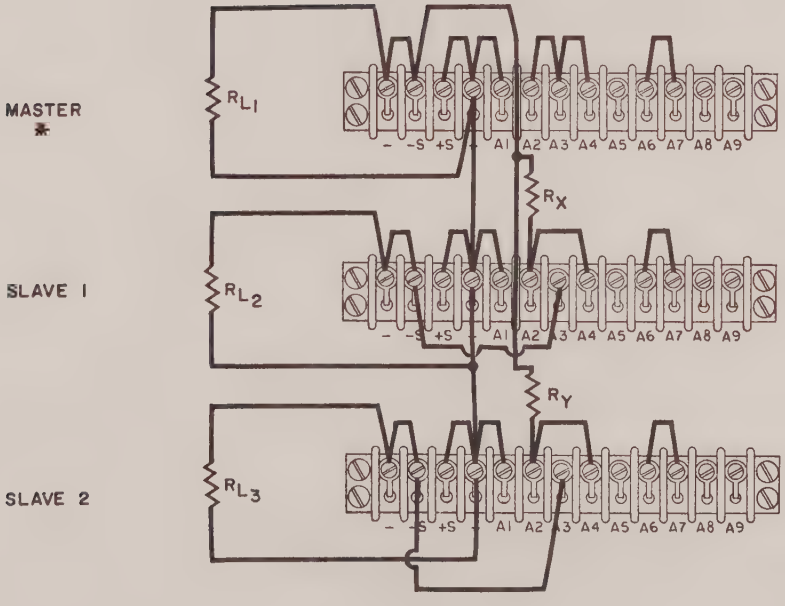
R_X = 20K

FIG. 3-3C
AUTO SERIES OPERATION
(THREE UNITS)



* MUST BE MOST NEGATIVE SUPPLY

FIG. 3-4A
AUTO TRACKING
(TWO UNITS)



* MUST BE MOST NEGATIVE SUPPLY

FIG. 3-4B
AUTO TRACKING
(THREE UNITS)

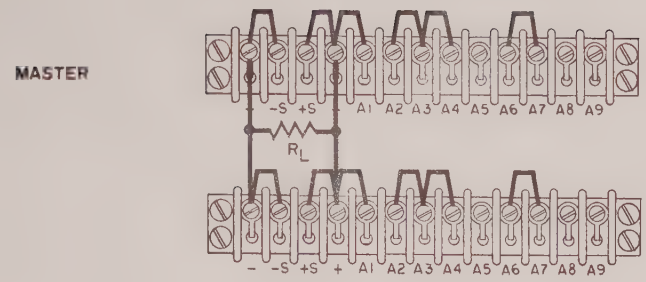
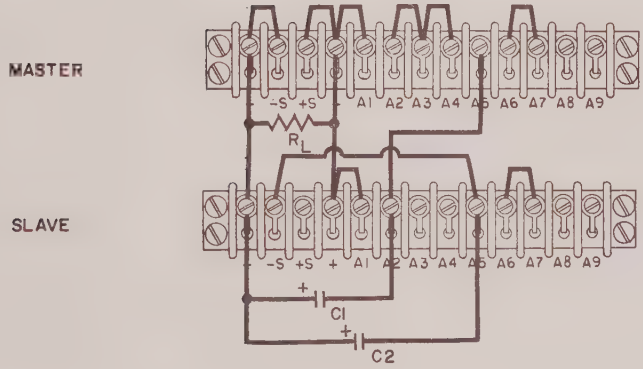
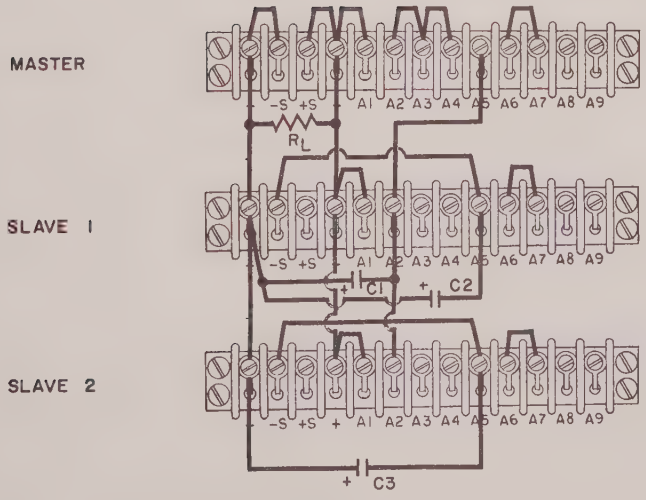


FIG. 3-5A
PARALLELED POWER SUPPLIES



C1, C2 = 20 μf 10V

FIG. 3-5B
AUTO PARALLEL
(TWO UNITS)



C1, C2, C3 = 20 μf 10V

FIG. 3-5C
AUTO PARALLEL
(THREE UNITS)

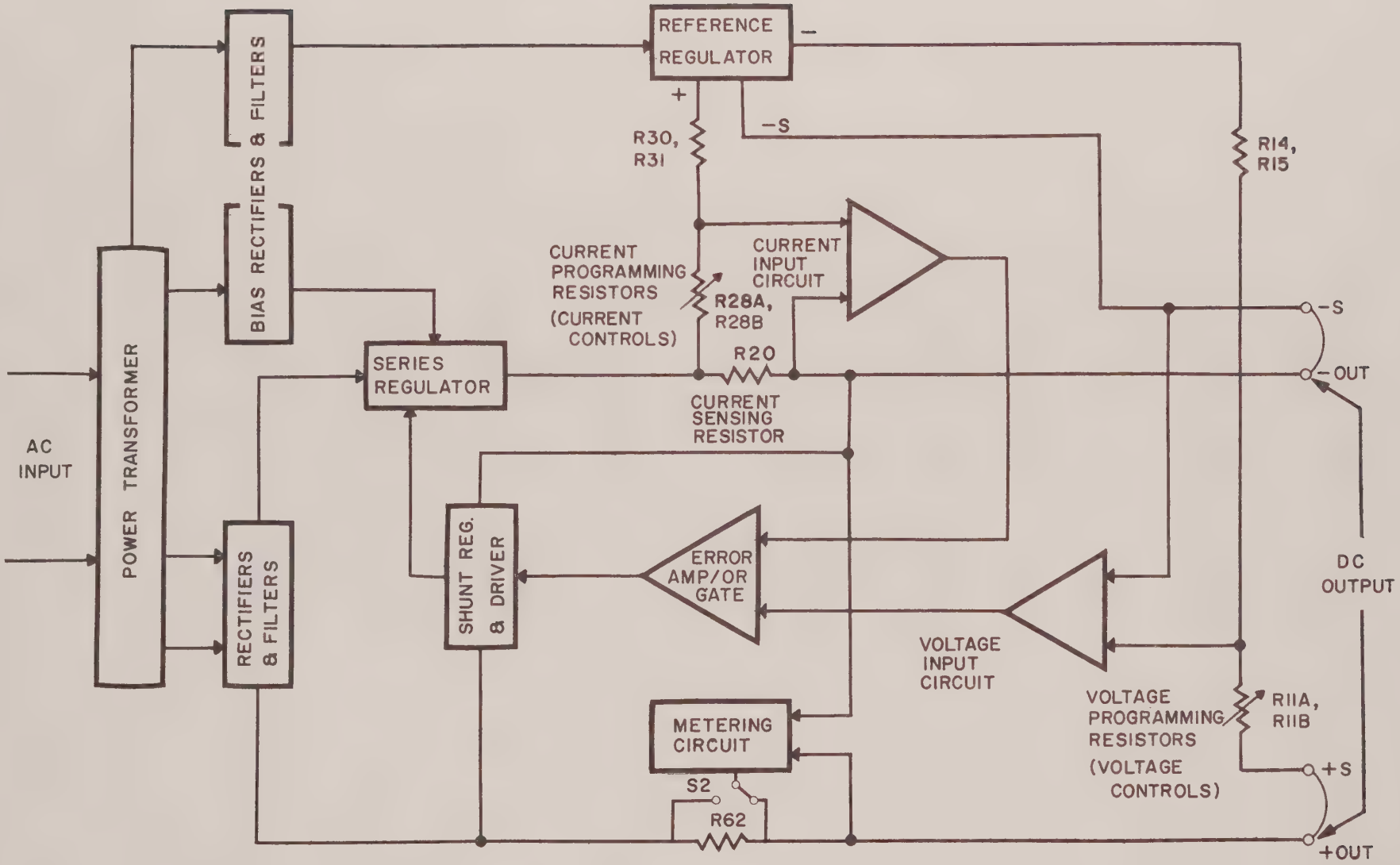


FIG. 4-1
BLOCK DIAGRAM

SECTION IV

PRINCIPLES OF OPERATION

4-1. BLOCK DIAGRAM DESCRIPTION (See figure 4-1.)

4-2. The power transformer isolates the ac input from the power supply and reduces it to the required voltage levels. The main rectifiers and filters produce a smoothed dc which is controlled by the series regulator to provide a well-regulated dc output across the -OUT and +OUT terminals. The bias rectifiers and filters produce dc bias and reference voltages for the power supply. A reference regulator assures well-regulated voltages where required.

4-3. The series regulator is controlled by either the voltage or current input circuits. The gating circuit assures that only one input circuit is used at a time.

4-4. The voltage and current input circuits operate in a similar manner. Each circuit has a differential amplifier that amplifies an error voltage that is proportional to the difference between the actual output and the programmed output. The programmed output is determined by the resistance of the programming resistors (voltage and current controls).

4-5. The voltage input circuit differential amplifier detects the error voltage that is proportional to the difference between the voltage across its programming resistors (R11A-R11B) and the dc output voltage. The error voltage is amplified and passed through the gating circuit to the series regulator driver. The amplified error voltage causes the series regulator to increase or decrease the output voltage as required to maintain a constant load voltage that is equal to the programmed voltage. In constant voltage operation, the gating circuit is biased to inhibit the input from the current input circuit.

4-6. The current input circuit differential amplifier detects the error voltage that is proportional to the difference between the voltage across its programming resistors (R28A-R28B) and the voltage across current sensing resistor R20. The voltage across the current sensing resistor is proportional to the load current. The series regulator responds to the amplified error voltage by increasing or decreasing the output current as required to maintain a constant load current. In constant current operation, the gating circuit is biased to inhibit the input from the voltage input circuit.

4-7. The current through the programming resistors must be held constant. The feedback loop of each input circuit strives to maintain a zero difference voltage at the input to its differential amplifier. Therefore, the programming current is equal to the applied reference regulator voltage divided by the parallel resistance of R14-R15 (voltage input) or R30-R31 (current input).

4-8. The shunt regulator and driver serve three functions:

a. Drives the series regulator.

b. With no load, the shunt regulator serves as a current bleed for the series regulator.

c. When the power supply dc output voltage is reduced (programmed down), the shunt regulator provides a low-resistance path for rapidly discharging the output capacitance.

4-9. The metering circuit can measure either the voltage or current output. Switch S2 selects the meter input. As shown, the circuit is monitoring output voltage. With the switch in the other position, output current (proportional to the voltage across R62) is monitored.

4-10. CIRCUIT DESCRIPTION (See figure 4-2 at back of manual.)

4-11. AC INPUT

4-12. The 105-125/210-250 vac, single phase, 50-440 cps input is applied to power transformer T1. As shown, the two primary windings are connected in parallel for the 105-125 vac input. For the 210-250 vac input the windings must be connected in series (paragraph 2-17). Each of the three secondary windings is center-tapped for full-wave rectification. The rectified output of each secondary is capacitively filtered (C16, C17, and C18). The main secondary winding has a capacitor (C21) directly across it to reduce voltage spikes. Resistor R48 is a bleed for discharging capacitor C18 when the power supply is turned off. The filtered dc output voltage of each secondary circuit is shown on the diagram for a 115-volt input and no load.

4-13. VOLTAGE INPUT

4-14. The voltage input circuit is basically a differential amplifier (Q1A-Q1B) that detects any voltage difference between the programmed output voltage and the actual output voltage. The differential amplifier output voltage varies in proportion to the output voltage variation. Transistors Q1A and Q1B are a matched pair in a single package to ensure that both are at the same temperature and thus improve stability.

4-15. There are two inputs to the base of Q1B; one determined by the negative output voltage and the other by the collector voltage of Q1A (positive feedback). If the negative output voltage goes to zero, R5 and R6 maintain a slightly negative base bias to ensure cut-off of Q1B (maximum output of Q1A). The positive feedback input is determined by resistors R12, R13, and R6; and is adjustable as shown in figure 4-2. Capacitor C4 improves loop stability by providing gain roll-off at high frequencies. The collector current is determined by the sum of the two base inputs. The output of Q1B is emitter-coupled (resistor R2) to Q1A.

4-16. The base input of Q1A is determined by the programmed voltage (voltage controls R11A-R11B). The collector current of Q1A is determined by the difference between its base and emitter inputs. This difference is an error voltage that is proportional to the difference between the programmed output voltage and the actual output voltage. The positive feedback enhances the dc gain of the differential amplifier and is factory adjusted to ensure stability. Capacitor C1 (across programming resistors R11A-R11B) reduces low frequency ripple and noise. Capacitor C2 provides high-frequency gain to reduce error voltages caused by transient and ripple voltages. (C2 effective only during high-speed programming; C1 disconnected). The collector output of Q1A is coupled to the gating circuit (base of transistor Q7).

4-17. VOLTAGE CLAMP

4-18. In constant voltage operation, the voltage programming current path is through voltage controls R11A-R11B, R14-R15 in parallel, the reference regulator, current sensing resistor R20 (via -S sensing lead), the series regulator, the main transformer secondary circuit, and back to the voltage controls via the +S sensing lead. In effect, the power supply output (- to + terminals) shunts the voltage programming current. This current is constant during constant voltage operation (paragraph 4-7). However, in constant current operation the power supply output voltage varies, causing the voltage programming current to vary. To prevent current sensing resistor R20 from interpreting this voltage programming current variation erroneously as a load change, the voltage at terminal A2 is clamped at approximately the same voltage present during constant voltage operation. This clamping action assures that the voltage programming current through current sensing resistor R20 is relatively constant during constant current operation.

4-19. In constant voltage operation, diode CR4 is reverse biased. Therefore, the base voltage of voltage clamp transistor Q3 is determined by voltage divider R7, R8, and R9. Under this condition, Q3 is cut off. When crossover to constant current operation occurs, the collector of Q1A goes more positive (output voltage falls) and CR4 conducts. The base voltage of Q3 also rises and both Q3 and CR3 conduct, clamping the voltage between terminals A2 and A8 (collector of Q3 electrically connected to A8 via R10, R45, CR13, CR14, and CR15). Diode CR3 protects the emitter-base junction of Q3 from excessive reverse voltage when the programmed voltage is rapidly reduced. The base bias is selected with allowance made for the emitter bias introduced by CR3 (CR3 requires approximately 0.7 volts to conduct).

4-20. In order to protect the differential amplifier, the base of Q1A is clamped by diodes CR1 and CR2 to prevent excessive base voltage in either direction. The diodes clamp the base to 0.7 volts. Resistor R1 provides current limiting.

4-21. CURRENT INPUT

4-22. The current input circuit is basically a differential amplifier (Q4A-Q4B) that detects any current difference between the programmed output current (proportional

to voltage across current controls) and the actual output current (proportional to voltage across current sensing resistor R20). The differential amplifier output voltage varies in proportion to the output current variation. Transistors Q4A and Q4B are a matched pair in a single package to ensure that both are at the same ambient temperature and thus improve stability.

4-23. The base input of Q4A is the voltage difference across current controls R28A-R28B, R18, and current sensing resistor R20. The current through R20 is the sum of the load current and a small meter current (via R57, R58, and R59). Voltage divider R18-R19 provides a small offset voltage to compensate for the voltage developed across R20 by the meter current. Because the programming current is constant in constant current operation (paragraph 4-7), the net voltage input to Q4A varies as the load current through R20 (error voltage). Capacitor C5 and resistor R27 provide gain roll-off at high frequencies. During constant voltage operation, diode CR5 clamps the voltage (0.7 volts) across current programming resistors R28A-R28B and current sensing resistor R20 to prevent the programming current from varying and thus affecting the regulation of the reference regulator. In addition, the base of Q4A is protected from excessive voltage. Resistor R21 reduces transients. The output of Q4A is emitter coupled (resistor R22) to Q4B whose collector output is coupled to the gating circuit (base of transistor Q6). Voltage divider R25-R26 biases the base of Q4B and maintains a slightly positive base bias when the output current goes to zero to ensure maximum output from Q4B.

4-24. GATING CIRCUIT

4-25. Gate Q6-Q7 provides an output to the series regulator driver circuit (base of Q8) that is determined by either the voltage or current input circuit. In constant voltage operation, Q7 controls the output and Q6 is held cut-off by the current input circuit. In constant current operation, Q6 controls the output and Q7 is held cut-off by the voltage input circuit. The input signals are applied to the bases of the transistors. Diodes CR7, CR8, CR9, and CR10 are forward biased and establish a threshold voltage for Q6-Q7 (emitter bias; approximately 2.8 volts). If the base of Q6 or Q7 rises above approximately 2.5 volts, the transistor will be cut-off.

4-26. Each transistor has a negative feedback network that provides roll-off of loop gain at high frequencies to prevent oscillations. For constant current operation, R34 and C6 maintain current loop stability. For constant voltage operation, R35 and C7 maintain voltage loop stability. Resistor R35 is variable so that the transient recovery time (refer to table 1-1) of the power supply can be adjusted. This control is factory adjusted so that with most loads, the fastest possible recovery time with no overshoot is obtained. It may be desirable to readjust R35 to compensate for the effects of transistor aging, etc.

4-27. SHUNT REGULATOR AND DRIVER

4-28. Transistor Q8 is an emitter-follower stage that provides power gain to compensate for transmission loss that attenuates the constant voltage and constant

current error signals. The base of Q8 is decoupled (R37, C10). The emitter output of Q8 drives the base of Q9.

4-29. Transistor Q9 is an emitter-follower with high current capability that performs three functions:

a. In response to the base input from Q8, transistor Q9 drives the series regulator (base of Q10). Voltage divider R43-R44 provides bias.

b. With no load connected, Q9 serves as a current bleed for the series regulator (shunt regulation).

c. When the output voltage is programmed down, Q9 conducts heavily and forward biases CR12 (normally reverse biased). This provides a low-resistance path for rapidly discharging the output capacitance (through R62) to the programmed output voltage (high-speed programming).

4-30. SERIES REGULATOR

4-31. The series regulator (Q10 and Q11) controls the output voltage and current in response to the voltage and current error signals. In constant voltage operation, the output voltage is adjusted so that the output voltage remains constant with changing loads. In constant current operation, the output current is maintained constant for changing loads and the output voltage is allowed to vary.

4-32. The current through Q10 (output current) is increased or decreased by the base drive supplied by Q9. Diodes CR17, CR18, and CR19 bias the base of Q11 -2.5 volts with respect to the emitter of Q10. The emitter bias of Q11 is determined by the voltage drop across Q10 which in turn depends on the current (voltage across Q10 decreases as load increases). Thus, the current through Q11 increases as the voltage drop across Q10 decreases. For small loads, most of the current from Q10 goes through R42. As the load increases, more current goes through Q11; this tends to maintain the voltage across Q10. The series regulator has the advantage of dissipating much of its power in the resistor instead of the transistors.

4-33. REFERENCE REGULATOR

4-34. The reference regulator supplies three reference voltages (+6.2, -6.2, and -12.6 vdc) for internal power supply operation. Transistor Q13 is the error detector/amplifier. Zener diodes VR1 and VR2 provide a reference voltage at the emitter of Q13. Voltage divider R50-R51 supplies an error voltage to the base of Q13 which amplifies and applies it to the base of series regulator Q14. The base drive of Q14 adjusts the voltage across Q14 as required to compensate for the reference output voltage error.

4-35. Resistor R52 sets the optimum current through the temperature-compensated zener diodes (VR1 and VR2) and in conjunction with resistor R49 equalizes the

current through VR1 and VR2 which have unequal circuit loading. Capacitor C15 stabilizes the loop. Resistor R55 improves the input voltage regulation. Diode CR27 provides necessary emitter bias for Q14. Resistor R56 reduces power dissipation in Q14.

4-36. METER CIRCUIT

4-37. A meter is provided for monitoring both output voltage and current. Switch S2 selects the meter input. As shown in figure 4-2, output current (proportional to voltage across R62) is being monitored. Resistors R60 and R61 (variable) calibrate the current range. Resistors R57, R58, and R59 (variable) calibrate the voltage range.

4-38. PROTECTION CIRCUITS

4-29. The constant voltage/constant current automatic crossover feature provides protection for the load. Diode CR33 protects the power supply from reverse voltage. Diode CR32 protects the series regulator from reverse voltage.

TABLE 5-1. TEST EQUIPMENT

Type	Required Characteristics	Use	Recommended Model
DC Voltmeter	Accuracy: 1% Approx. ranges: 0-2.5 volts 0-50 volts 0-150 volts Input resistance: 20,000 ohms/volt(min.)	Measure dc voltages	HP412A
AC Voltmeter	Accuracy: 2% Sensitivity: 1 mv full scale (min.)	Measure ac voltages and ripple	HP403B
Variable Voltage Transformer	Range: 90-130 volts Equipped with voltmeter accurate within 1 volt	Vary and measure ac input voltage	---
Oscilloscope	Sensitivity: 200μv/cm (min.) Differential input	Measure ripple and transient response	HP130C
Differential Voltmeter	Sensitivity: 1 mv full scale (min.)	Measure regulation; Calibrate meter	HP741 (See note)
Mercury Wetted Relay	1μsec rise and fall time	Measure transient response	---
Resistive Loads	80 ohms, ±5%, 75w	Power supply load	---
Current Sensing Resistor	1 ohm, ±1%, 200w 20 ppm temp. coeff., 4 terminals	Measure current; calibrate meter	---

TABLE 5-1. TEST EQUIPMENT (cont.)

Type	Required Characteristics	Use	Recommended Model
Resistor	1k, ±1%, 2w non-inductive	Measure impedance	---
Capacitor	500μfd, 50 vdcw	Measure impedance	---
Resistor	100 ohms, ±5%, 10w	Measure impedance	---
Audio Oscillator	5 cps-600 kc Accuracy: 2% Output: 10 vrms	Measure impedance	HP200CD
Shorting Switch	---	Constant current load regulation	---
Controlled-Temperature Oven	0-50°C	Measure temperature stability	---
Resistance Box	0-20k Accuracy: 0.1% + 1 ohm Make-before-break contacts	Measure programming coefficients	H-LAB 6931A

NOTE

A satisfactory substitute for a differential voltmeter is to arrange a reference voltage source and null detector as shown in figure 5-1. The reference voltage source is adjusted so that the voltage difference between the supply being measured and the reference voltage will have the required resolution for the measurement being made. The voltage difference will be a function of the null detector that is used. Satisfactory null detectors are: HP405AR digital voltmeter, HP 412A dc voltmeter, HP419A null detector, a dc coupled oscilloscope utilizing differential input, or a 50 mv meter movement with a 100 division

scale. A 2 mv change in voltage will result in a meter deflection of four divisions.

CAUTION

Care must be exercised when using an electronic null detector in which one input terminal is grounded to avoid ground loops and circulating currents.

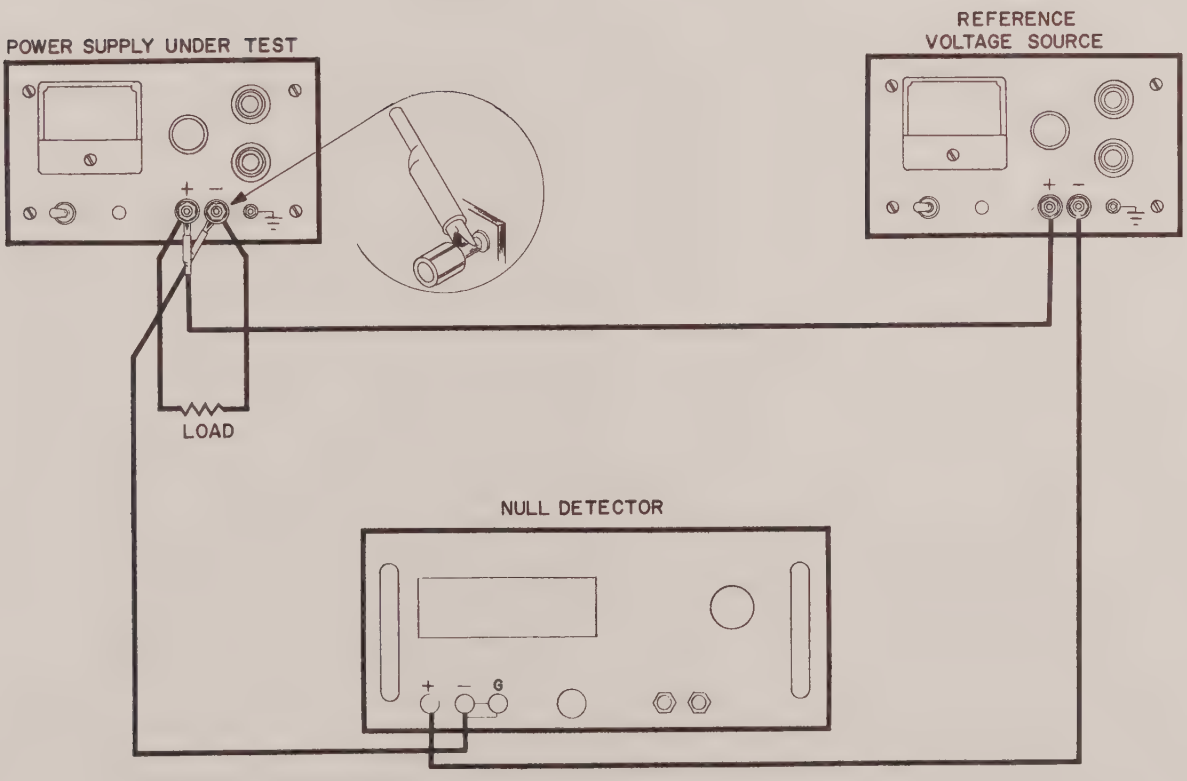


FIG. 5-1
DIFFERENTIAL VOLTMETER SUBSTITUTE,
TEST SETUP

SECTION V

MAINTENANCE

5-1. GENERAL

5-2. Table 5-1 lists the type of test equipment, its required characteristics, its use, and a recommended model for performing the instructions given in this section. Upon receipt of the power supply, the performance check (para. 5-7) should be made. This check is suitable for incoming inspection. Additional specification checks are given in paragraphs 5-24 through 5-40. If a fault is detected in the power supply while making the performance check or during normal operation, proceed to the troubleshooting procedures (para. 5-43). After troubleshooting and repair (para. 5-53), perform any necessary adjustments and calibrations (para. 5-55). Before returning the power supply to normal operation, repeat the performance check to ensure that the fault has been properly corrected and that no other faults exist. Before doing any maintenance checks, turn the power supply on, allow a half-hour warm-up, and read the measurement techniques (para. 5-3).

5-3. MEASUREMENT TECHNIQUES

5-4. Measurements should be made at the same terminals of the power supply at which the load is connected (do not measure at front terminals if load is connected at rear terminals). A measurement made across the load includes the effect of the impedance of the leads connecting the load; these leads can have an impedance several orders of magnitude greater than the output impedance of the power supply. When measuring the output at the rear of the power supply, use the -S and +S terminals; when measuring at the front terminals, connect the measuring device as shown in figure 5-2 (it is important to connect at A and not at B).

5-5. For output current measurements, the current monitoring resistor should be a four-terminal resistor. The four terminals are connected as shown in figure 5-3.

5-6. When using an oscilloscope, ground one terminal of the power supply and ground the case at the same ground point. Make certain that the case is not also grounded by some other means (power cord). Connect both oscilloscope input leads to the power supply ground terminal and check that the oscilloscope is not exhibiting a ripple or transient due to ground loops, pick-up, or other means.

5-7. PERFORMANCE CHECK

5-8. GENERAL

5-9. The performance check is made using a 115-volt, 60-cps, single-phase input power source. The performance check is normally made at a constant ambient room temperature. The temperature range specification can be verified

by doing the performance check (except temperature stability check) at a controlled temperature of 0°C and at a controlled temperature of 50°C. If the correct result is not obtained for a particular check, do not adjust any controls; proceed to trouble-shooting (para. 5-43).

5-10. RATED OUTPUT AND METER ACCURACY

5-11. CONSTANT VOLTAGE. Proceed as follows:

a. Connect the 80-ohm load resistor and the differential voltmeter across the front terminals.

b. Turn front-panel CURRENT control fully clockwise (maximum).

c. Set front-panel METER switch to VOLTS.

d. Turn front-panel VOLTAGE control until front-panel meter indicates 40.0 volts.

e. The differential voltmeter should indicate 40.0 ±0.8 volts.

5-12. CONSTANT CURRENT. Proceed as follows:

a. Connect test setup shown in figure 5-4.

b. Turn front-panel VOLTAGE control fully clockwise (maximum).

c. Set front-panel METER switch to AMPS.

d. Turn front-panel CURRENT control until front-panel meter indicates 0.50 ampere.

e. The differential voltmeter should indicate 0.50 ±0.01 volts.

5-13. LINE REGULATION

5-14. CONSTANT VOLTAGE. Proceed as follows:

a. Connect the 80-ohm load resistor and the differential voltmeter across the front terminals.

b. Turn front-panel CURRENT control fully clockwise (maximum).

c. Connect the variable voltage transformer between the input power source and the power supply power input. Adjust the variable voltage transformer to 105 vac.

d. Turn front-panel VOLTAGE control until the differential voltmeter indicates 40.0 volts.

e. Adjust the variable voltage transformer to 125 VAC.

f. Differential voltmeter indication should change by less than 6.0 mv.

5-15. CONSTANT CURRENT. Proceed as follows:

a. Connect test setup shown in figure 5-4.

b. Turn front-panel VOLTAGE control fully clockwise (maximum).

c. Connect the variable voltage transformer between the input power source and the power supply power input. Adjust the variable voltage transformer to 105 VAC.

d. Set front-panel METER switch to AMPS.

e. Turn front-panel CURRENT control until front-panel meter indicates 0.50 ampere.

f. Record voltage indicated on differential voltmeter.

g. Adjust the variable voltage transformer to 125 VAC.

h. Differential voltmeter indication should change by less than 0.25 mv.

5-16. LOAD REGULATION

5-17. CONSTANT VOLTAGE. Proceed as follows:

a. Connect the 80 ohm load resistor and the differential voltmeter across the front terminals.

b. Turn front-panel CURRENT control fully clockwise (maximum).

c. Set front-panel METER switch to AMPS.

d. Turn front-panel VOLTAGE control until front-panel meter indicates 0.50 ampere.

e. Record voltage indicated on differential voltmeter.

f. Disconnect load resistor

g. Differential voltmeter indication should change by less than 6.0 mv.

5-18. CONSTANT CURRENT. Proceed as follows:

a. Connect test setup shown in figure 5-4.

b. Turn front-panel VOLTAGE control fully clockwise (maximum).

c. Set front-panel METER switch to AMPS.

d. Turn front-panel CURRENT control until front-panel meter indicates 0.50 ampere.

e. Record voltage indicated on differential voltmeter.

f. Close the shorting switch.

g. Differential voltmeter indication should change by less than 0.25 mv.

5-19. RIPPLE AND NOISE

5-20. CONSTANT VOLTAGE. Proceed as follows:

a. Connect the 80-ohm load resistor and the ac voltmeter across the front terminals.

b. Turn front-panel CURRENT control fully clockwise (maximum).

c. Connect the variable voltage transformer between the input power source and the power supply power input. Adjust the variable voltage transformer to 125 vac.

d. Set front-panel METER switch to AMPS.

e. Turn front-panel VOLTAGE control until front-panel meter indicates 0.50 ampere.

f. The ac voltmeter should indicate less than 0.20 mv on the 1.0 mv range.

5-21. CONSTANT CURRENT. Proceed as follows:

a. Connect test setup shown in figure 5-5.

b. Turn front-panel VOLTAGE control fully clockwise (maximum).

c. Connect the variable voltage transformer between the input power source and the power supply power input. Adjust the variable voltage transformer to 125 vac.

d. Set front-panel METER switch to AMPS.

e. Turn front-panel CURRENT control until front-panel meter indicates 0.50 ampere.

f. The ac voltmeter should indicate less than 0.20 mv on the 1.0 mv range.

5-22. TRANSIENT RECOVERY TIME

5-23. Proceed as follows:

a. Connect test setup shown in figure 5-7.

b. Turn front-panel CURRENT control fully clockwise (maximum).

c. Set front-panel METER switch to AMPS.

d. Adjust front-panel VOLTAGE control until front-panel meter indicates 0.50 ampere.

e. Energize the mercury-wetted relay from 115-volt, 60-cps, single-phase power source.

f. Oscilloscope display should be as shown in figure 5-8.

5-24. ADDITIONAL SPECIFICATION CHECK

5-25. TEMPERATURE COEFFICIENT

5-26. CONSTANT VOLTAGE. Proceed as follows:

a. Connect the 80-ohm load resistor and the dc voltmeter across the front terminals.

b. Turn front-panel CURRENT control fully clockwise (maximum).

c. Turn front-panel VOLTAGE control until the dc voltmeter indicates 40.0 volts.

d. Insert the power supply into the controlled-temperature oven (dc voltmeter remains outside oven). Set the temperature to 30°C and allow a half-hour warm-up.

e. Record the dc voltmeter indication.

f. Raise the temperature to 40°C and allow a half-hour warm-up.

g. DC voltmeter indication should change by less than 70 mv from indication recorded in step e.

5-27. CONSTANT CURRENT. Proceed as follows:

a. Connect test setup shown in figure 5-4.

b. Turn front-panel VOLTAGE control fully clockwise (maximum).

c. Turn front-panel CURRENT control until the differential voltmeter indicates 500.0 mv.

d. Insert the power supply into the controlled-temperature oven (differential voltmeter remains outside oven). Set the temperature to 30°C and allow a half-hour warm-up.

e. Record the differential voltmeter indication.

f. Raise the temperature to 40°C and allow a half-hour warm-up.

g. Differential voltmeter indication should change by less than 6.0 mv from indication recorded in step e.

5-28. OUTPUT STABILITY

5-29. CONSTANT VOLTAGE. Proceed as follows:

a. Connect the 80-ohm load resistor and the dc voltmeter across the front terminals.

b. Turn front-panel CURRENT control fully clockwise (maximum).

c. Turn front-panel VOLTAGE control until the dc voltmeter indicates 40.0 volts.

d. Allow a half-hour warm-up and then record the dc voltmeter indication.

e. After eight hours, dc voltmeter indication should change by less than 35.0 mv from indication recorded in step d.

5-30. CONSTANT CURRENT. Proceed as follows:

a. Connect test set up shown in figure 5-4.

b. Turn front-panel VOLTAGE control fully clockwise (maximum).

c. Turn front panel CURRENT control until the differential voltmeter indicates 500.0 mv.

d. Allow a half-hour warm-up and then record the differential voltmeter indication.

e. After eight hours, differential voltmeter indication should change by less than 1.5 mv from indication recorded in step d.

5-31. REMOTE PROGRAMMING

5-32. CONSTANT VOLTAGE. Proceed as follows:

a. Turn-off power supply and arrange rear terminal strapping pattern for constant voltage remote resistance programming as shown in figure 3-2B; use the resistance box (set to 10,000 ohms) for the remote programming resistance. (Refer to paragraphs 3-17 through 3-21.)

b. Turn front-panel CURRENT control fully clockwise (maximum).

c. Connect the 80-ohm load resistor and the dc voltmeter across the front terminals.

d. Turn-on power supply, allow a half-hour warm-up and then record the dc voltmeter indication.

e. Increase the remote programming resistance in 500-ohm steps to 13,000 ohms; record the dc voltmeter indication at each step. The voltage should increase 1.0 $\pm$0.02 volts at each step.

f. Set the remote programming resistance to 17,000 ohms and repeat step e until the remote programming resistance reaches 20,000 ohms.

g. Turn-off power supply, reconnect normal strapping pattern (figure 3-2A), and then turn-on power supply.

5-33. CONSTANT CURRENT. Proceed as follows:

a. Turn-off power supply and arrange rear terminal strapping pattern for constant current remote resistance programming as shown in figure 3-2D; use resistance box (set to 600 ohms) for the remote programming resistance. (Refer to paragraphs 3-18 and 3-23 through 3-25.)

b. Turn front-panel VOLTAGE control fully clockwise (maximum).

c. Connect test setup shown in figure 5-4.

d. Turn-on power supply, allow a half-hour warm-up and then record the differential voltmeter indication.

e. Increase the remote programming resistance in 30-ohm steps to 900 ohms; record the differential voltmeter indication at each step. The voltage should increase 10.0 $\pm$1.0 mv at each step.

f. Set the remote programming resistance to 1,200 ohms and repeat step e until the remote programming resistance reaches 1,500 ohms.

g. Turn-off power supply, reconnect normal strapping pattern (figure 3-2A), and then turn-on power supply.

5-34. HIGH-SPEED VOLTAGE PROGRAMMING

5-35. NO LOAD. Proceed as follows:

a. Turn-off power supply and arrange rear terminal strapping pattern for high speed voltage programming as shown in figure 3-2F (programming resistor should be 20,000 ohms obtained from resistance box). The mercury-wetted relay should be energized from a 115-volt, 60-cps, single-phase power source.

b. Connect the oscilloscope across front terminals. Turn-on power supply.

c. Observe oscilloscope display.

Volts	Rise Time	Fall Time
0-40	30v/millisecond	---
40-1	---	30v/millisecond
1-0	---	0.5 /millisecond

d. Remove the mercury-wetted relay and the oscilloscope. Connect the ac voltmeter across the front terminals.

e. The ac voltmeter should indicate less than 2.0 mv (ripple and noise).

5-36. FULL LOAD. Proceed as follows:

a. Turn-off power supply and arrange rear terminal strapping pattern for high-speed voltage programming as shown in figure 3-2F (programming resistor should be 20,000 ohms obtained from resistance box). The mercury-wetted relay should be energized from a 115-volt, 60 cps, single-phase power source.

b. Set front-panel METER switch to AMPS.

c. Turn front-panel CURRENT control until front panel meter indicates 0.55 ampere.

d. Connect the 80-ohm load resistor and the oscilloscope across front terminals. Turn-on power supply.

e. Observe oscilloscope display.

Volts	Rise Time	Fall Time
0-40	20v/millisecond	---
40-1	---	40v/millisecond
1-0	---	0.7v/millisecond

f. Remove the mercury-wetted relay and the oscilloscope. Connect the ac voltmeter across the front terminals. (The 80-ohm load resistor remains.)

g. The ac voltmeter should indicate less than 2.0 mv (ripple and noise).

h. Turn-off power supply, reconnect normal strapping pattern (figure 3-2A), and then turn-on power supply.

5-37. OUTPUT IMPEDANCE

5-38. Proceed as follows:

a. Connect test setup shown in figure 5-6.

b. Turn front-panel CURRENT control fully clockwise (maximum).

c. Set front-panel METER switch to VOLTS.

d. Adjust front-panel VOLTAGE control until front-panel meter indicates 20.0 volts.

e. Adjust the audio oscillator for a 10-vrms (Ein), 5-cps output.

f. Calculate and record the output impedance using the following formula:

$$Z\text{out} = EoR/(Ein - Eo)$$

R=1,000 ohms; Eo measured across power supply front terminals using the ac voltmeter; Ein measured across audio oscillator output terminals using the ac voltmeter.

g. Using the formula given in step f, calculate and record the output impedance for audio oscillator frequencies of 100 cps, 1,000 cps, 100 kc, and 600 kc at 10 vrms.

h. The output impedances calculated and recorded in steps f and g should fall into the following ranges:

(1) dc to 100 cps; less than 0.01 ohm.
(2) 100 cps to 1 kc; less than 0.02 ohm.
(3) 1 kc to 100 kc; less than 0.5 ohm.
(4) 100 kc to 1 mc; less than 3 ohms.

5-39. OUTPUT INDUCTANCE

5-40. Proceed as follows:

a. Repeat steps a through d of paragraph 5-38.

b. Adjust the audio oscillator for 10-vrms (Ein), 10-kc output.

c. Calculate and record the output impedance using the following formula:

$$L = X1/2\pi f$$

X1 is the output impedance (Z out) calculated in steps f and g of paragraph 5-38; f

is the frequency of the audio oscillator (determines which Z out is used).

NOTE

The equation assumes that $X1 \gg R$ out and therefore $X1 = Z$ out.

d. Using the formula given in step c, calculate and record the output inductance for audio oscillator frequencies of 50 kc and 100 kc at 10 vrms.

e. The output inductance calculated in steps c and d should not exceed 0.16 microhenry.

5-41. COVER REMOVAL

5-42. The top and bottom covers are removed by removing both sets of four attaching screws. If the power supply has a case instead of covers, remove the two attaching screws at the bottom rear of the power supply.

5-43. TROUBLESHOOTING

5-44. GENERAL

5-45. If a fault in the power supply is suspected, remove the covers (para. 5-41) and visually inspect for broken connections, burned components, etc. If the fault is not detected visually, proceed to trouble analysis (para. 5-46). If the fault is detected visually or via trouble analysis, correct it and then do the performance check (para. 5-7). If a part is replaced, refer to repair and replacement paragraph 5-53 and to adjustments and calibrations paragraph 5-55.

5-46. TROUBLE ANALYSIS

5-47. GENERAL. Before attempting trouble analysis, a good understanding of the principles of operation should be acquired by reading Section IV of this manual. Once the principles of operation are understood, logical application of this knowledge in conjunction with normal voltage table 5-2 should suffice to isolate a fault to a part or small group of parts. As additional aids, the following are given.

a. Procedure for checking the reference regulator circuit. Trouble in this circuit could show up in many ways because it supplies internal operating voltages for the power supply.

b. Procedures for checking the voltage feedback loop for the two most common troubles; high or low output voltage (table 5-3 or 5-4, respectively).

c. Table 5-5 which gives the probable causes for several common troubles.

5-48. A defective part should be replaced (refer to the parts list in Section VI). Test points called out in the procedures are identified on the schematic diagram (figure 4-2).

5-49. REFERENCE REGULATOR. Turn the front-panel VOLTAGE and CURRENT controls fully clockwise (maximum). Make an ohmmeter check to be certain that neither the positive nor negative terminal is grounded. Turn-on power supply (no load connected) and proceed as follows:

a. Using the dc voltmeter, check the -12.6 volt regulated bias between test points -S and 38. If the voltage indication is not -12.6 $\pm$1.0 vdc, transistor Q13 or Q14 is probably defective.

b. Using the dc voltmeter, check the negative reference voltage between test points -S and 32. If the voltage indication is not -6.2 $\pm$0.30 vdc, diode VR2 is probably defective.

c. Using the dc voltmeter, check the positive reference voltage between test points -S and 33. If the voltage indication is not +6.2 $\pm$0.30 vdc, diode VR1 is probably defective.

5-50. HIGH OUTPUT VOLTAGE. Proceed as follows:

a. Turn front-panel CURRENT control fully clockwise (maximum).

b. Turn-on power supply (no load connected).

c. Set front-panel METER switch to VOLTS.

d. Turn front-panel VOLTAGE control to mid-position.

e. Using the dc voltmeter, proceed as instructed in table 5-3.

5-51. LOW OUTPUT VOLTAGE. Proceed as follows:

a. Turn front-panel CURRENT control fully clockwise (maximum).

b. Turn-on power supply (no load connected).

c. Set front-panel METER switch to VOLTS.

d. Set front-panel VOLTAGE control to mid-position.

e. Remove transistor Q6 from its socket.

f. Turn the front-panel VOLTAGE control clockwise and observe the front-panel meter to see if the 40 vdc output can be obtained. If it can, the probable

cause of the low output voltage is one or more of the following:

(1) Q6 shorted.

(2) CR5 shorted.

(3) R30 open.

(4) Q4B shorted.

g. If the 40 vdc output cannot be obtained in step f, replace transistor Q6 in its socket and set the front-panel VOLTAGE control to mid-position.

h. Using the dc voltmeter, proceed as instructed in table 5-4.

5-52. COMMON TROUBLES. Table 5-5 gives the symptoms, checks, and probable causes for common troubles. The checks should be made using a 115-volt, 60-cps, single-phase power input and the test equipment listed in table 5-1.

5-53. REPAIR AND REPLACEMENT

5-54. Before servicing etched circuit boards, refer to figure 5-9. When replacing semiconductor devices, make certain that a mica washer and a good silicone grease (Dow Corning silicone grease #3 or equivalent) are used for mounting in order to provide good heat conduction to the chassis. After replacing a semiconductor device, refer to table 5-6 for checks and adjustments that may be necessary. If a check indicates a trouble, refer to paragraph 5-43. If an adjustment is necessary, refer to paragraph 5-55.

5-55. ADJUSTMENTS AND CALIBRATIONS

5-56. GENERAL

5-57. Adjustments and calibrations may be required after performance testing (para. 5-7), additional specification testing (para. 5-24), troubleshooting (para. 5-43) or repair and replacement (para. 5-53). Test points called out in the procedures are identified on the schematic diagram (figure 4-2). If an adjustment or calibration cannot be performed, troubleshooting (para. 5-43) is required. Table 5-7 summarizes the adjustments and calibrations. The adjustments and calibrations are performed using a 115-volt, 60-cps, single-phase power input to the power supply.

5-58. METER ZERO

5-59. Proceed as follows:

a. Turn-off power supply and allow 30 seconds for all capacitors to discharge.

b. Rotate meter zero set screw (figure 3-1) clockwise until the front-panel meter pointer is to the right of zero and moving to the left towards zero. Stop when pointer is on zero. If the pointer overshoots zero, continue rotating clockwise and repeat this step.

c. When the pointer is exactly on zero, rotate the adjustment screw approximately 15 degrees counterclockwise to free the adjustment screw from the meter suspension. If pointer moves, repeat steps a through c.

5-60. VOLTMETER TRACKING

5-61. Proceed as follows:

a. Connect the dc voltmeter across the output terminals of the power supply.

b. Set front-panel METER switch to VOLTS.

c. Adjust front-panel VOLTAGE control until dc voltmeter indicates 40.0 volts.

d. Adjust R59 until the front-panel meter indicates 40.0 volts.

5-62. AMMETER TRACKING

5-63. Proceed as follows:

a. Connect test setup shown in figure 5-4.

b. Turn front-panel VOLTAGE control fully clockwise (maximum).

c. Adjust front-panel CURRENT control until differential voltmeter indicates 0.50 volt.

d. Adjust R61 until front-panel ammeter indicates 0.50 ampere.

5-64. ZERO VOLTAGE OUTPUT

5-65. Proceed as follows:

a. Connect a jumper between the A2 and +S terminals on the rear terminal strip of the power supply.

b. Connect the differential voltmeter between the +S and -S terminals.

c. Connect the resistance box in place of resistor R5.

d. Adjust the resistance box so that the voltage indicated by the differential voltmeter is between zero and -25 mv.

e. Choose resistor R5 equal to the resistance value required in step d.

5-66. CONSTANT VOLTAGE PROGRAMMING CURRENT

5-67. Proceed as follows:

a. Connect a 20K, 0.1%, 1/2w resistor between terminals +S and A2 on the rear terminal strip of the power supply.

b. Disconnect the jumper between terminals A3 and A4.

c. Connect the resistance box in place of resistor R15 (shunt).

d. Connect the differential voltmeter between the +S and -S terminals.

e. Adjust the resistance box so that the differential voltmeter indicates 40 $\pm$0.2 volts.

f. Choose resistor R15 (shunt) equal to the resistance required in step e.

5-68. ZERO CURRENT OUTPUT

5-69. Proceed as follows:

a. Connect test setup shown in figure 5-4.

b. Connect a jumper between the A5 and A6 terminals on the rear terminal strip of the power supply.

c. Connect the resistor box in place of resistor R25.

d. Adjust the resistor box so that the voltage indicated by the differential voltmeter is between zero and -25 mv.

e. Choose resistor R25 equal to the resistance value required in step d.

5-70. CONSTANT CURRENT PROGRAMMING CURRENT

5-71. Proceed as follows:

a. Connect test setup shown in figure 5-4.

b. Connect a 1500 ohm, 0.1%, 1/2w resistor between terminals A5 and A7 on the rear terminal strip of the power supply.

c. Disconnect the jumper between terminals A6 and A7.

d. Connect the resistance box in place of resistor R31 (shunt).

e. Adjust the resistance box so that the differential voltmeter indicates 0.5 volts $\pm$2.5 mv.

f. Choose resistor R31 (shunt) equal to the resistance value required in step e.

5-72. OUTPUT VOLTAGE LINE REGULATION

5-73. Proceed as follows:

a. Connect the differential voltmeter between -S and +S.

b. Connect the resistance box in place of resistor R55.

c. Set front-panel METER switch to VOLTS.

d. Adjust front-panel VOLTAGE control until front-panel meter indicates 40.0 vdc.

e. Connect the variable voltage transformer between input power source and power supply power input.

f. Adjust variable voltage transformer to 105 volts.

g. Adjust the resistance box so that the voltage indicated by the differential voltmeter does not change by more than 6.0 mv as the variable voltage transformer is varied from 105 to 125 volts.

h. Choose resistor R55 equal to the resistance value required in step e. Remove the variable voltage transformer.

5-74. -6.2 VOLT REFERENCE LOAD REGULATION

5-75. Proceed as follows:

a. Connect the 80-ohm load resistor across the power supply front terminals and turn the CURRENT control fully clockwise (maximum).

b. Connect the differential voltmeter between -S and 32 (across diode VR2).

c. Set front-panel METER switch to AMPS.

d. Adjust the front-panel VOLTAGE control until the front-panel meter indicates 0.50 ampere.

e. Record the differential voltmeter indication.

f. Disconnect one end of the load resistor. The differential voltmeter indication should not change by more than 0.2 mv.

g. If the voltage change exceeds 0.2 mv, replace diode VR2 and repeat steps a through f.

5-76. +6.2 VOLT REFERENCE LOAD REGULATION

5-77. Proceed as follows:

a. Connect test setup shown in figure 5-4, except connect the differential voltmeter between -S and 33 (across diode VR1).

b. Turn front-panel VOLTAGE control fully clockwise (maximum).

c. Set front-panel METER switch to AMPS.

d. Adjust the front-panel CURRENT until the front-panel meter indicates 0.50 ampere.

e. Record the differential voltmeter indication.

f. Short the load resistor (close shorting switch). The differential voltmeter indication should not change by more than 0.2 mv.

g. If the voltage change exceeds 0.2 mv, replace diode VR1 and repeat steps a through f.

5-78. TRANSIENT RESPONSE

5-79. Proceed as follows:

a. Connect test setup shown in figure 5-7.

b. Turn front-panel CURRENT control fully clockwise (maximum).

c. Set front-panel METER switch to AMPS.

d. Adjust front-panel VOLTAGE control until front-panel meter indicates 0.50 ampere.

e. Energize the mercury-wetted relay from a 115-volt, 60-cps, single-phase power source.

f. Adjust resistor R35 so that the transient response displayed on the oscilloscope is as shown in figure 5-8.

5-80. CONSTANT VOLTAGE LOAD REGULATION

5-81. Proceed as follows:

a. Connect the 80-ohm load resistor and differential voltmeter across power supply front terminals.

b. Turn front-panel CURRENT control fully clockwise (maximum).

c. Set front-panel METER switch to AMPS.

d. Adjust front-panel VOLTAGE control until front-panel meter indicates 0.50 ampere.

e. Using a small screwdriver, turn resistor R6 fully counterclockwise.

f. Disconnect one end of the load resistor.

g. Record the differential voltmeter indication.

h. Reconnect the load to the power supply.

i. Record the differential voltmeter indication.

j. The voltage difference between steps g and i represents the load regulation and may be reduced to near zero millivolts.

k. Turn resistor R6 one-quarter-turn clockwise and repeat steps f through i.

l. Repeat step k until the voltage difference between steps g and i is as close to zero as possible. Adjusting R6 causes the output voltage of the power supply to change slightly. Therefore, repeat step d each time before repeating steps g through i.

m. If R6 is adjusted almost fully clockwise, a negative output impedance may occur, that is, the output voltage will increase when the load resistor is connected to the power supply. This situation is to be avoided and therefore R6 should be backed off.

TABLE 5-2. NORMAL VOLTAGE

From (+) to (-)	Voltage	Typical Peak-to-peak Ripple
-S 32	6.2 ±0.3 vdc	0.1 mv
-S 38	12.6 ±0.7 vdc	<5 mv
-S 12	0.05 ±0.02 vdc	<0.2 mv
-S A2	0.05 ±0.03 vdc	<0.2 mv
-S 11	0.05 ±0.03 vdc	<0.2 mv
33 -S	6.2 ±0.3 vdc	0.4 mv
17 -S	2.8 ±0.2 vdc	<0.2 mv
14 -S	0.05 ±0.02 vdc	<1 mv
A7 -S	0.6 ±0.1 vdc	<1 mv
13 -S	0.5 ±0.2 vdc	<1 mv
10 -S	0.3 ±0.2 vdc	<5 mv
16 -S	2.6 ±0.3 vdc	<0.4 mv
15 -S	6.2 ±0.3 vdc	<1 mv
A8 -S	0 vdc	<0.3 mv
27 +S	0 vdc	----
27 A9	60 ±3.0 vdc	0.8 V
A8 20	0.2 ±0.1 vdc	<2 mv
A8 23	2.4 ±0.2 vdc	<8 mv
A8 22	10 ±1.0 vdc	<0.2 V
28 A8	2.5 ±0.2 vdc	<8 mv
28 31	47 ±3.0 vdc	3.2 V

TABLE 5-2. NORMAL VOLTAGE (cont.)

From (+)	to (-)	Voltage	Typical Peak-to-peak Ripple
18	A8	1 ±0.3 vdc	<3 mv
34	32	0.55 ±0.1 vdc	----
19	A8	0.3 ±0.1 vdc	<1 mv
40	39	0.18 ±0.01 vdc	----
10	11	47 vac	----
10	12	94 vac	----
4	5	37 vac	----
4	6	74 vac	----
7	8	18 vac	----
7	9	36 vac	----

NOTE

These measurements were made with a 115-volt, 60-cps, single-phase power input; the front-panel VOLTAGE control adjusted for a 40-volt output; no load connected; and the negative output terminal grounded. The dc and ac measurements were made using the dc and ac voltmeters, respectively. The ripple measurements were made using the oscilloscope.

TABLE 5-3. HIGH OUTPUT VOLTAGE, TROUBLESHOOTING

Step	Meter Common	Meter Positive	Response	Probable Cause
1	A8	20	0 vdc or more positive	a. Q10, Q11 shorted b. CR32 shorted
			-0.2 vdc or more negative	a. Q9 open b. C8 open c. C10 shorted
2	-S	18	+1 vdc or more positive	a. Q8 open b. R36 open
			+1 vdc or more negative	a. A7 open b. R33 shorted c. CR7, 8, 9, 10 any or all shorted d. CR13, 14, 15 any or all shorted
3	-S	16	+2.5 vdc or more negative	Q7 open
			+2.5 vdc or more positive	a. Q1A open b. R3 shorted c. R6 and R13 open
4	-S	A2	0 vdc or more negative	a. Strap A2 to A4 open b. Strap +S to + out open c. Voltage Control R11 open
			0 vdc or more positive	a. R1 open b. Q1A open c. Q1B shorted

TABLE 5-4. LOW OUTPUT VOLTAGE, TROUBLESHOOTING

Step	Meter Common	Meter Positive	Response	Probable Cause
1	A8	20	-0.2 vdc or more negative	a. Q10 open b. R20 or R62 open
			-0.2 vdc or more positive	a. CR12 or Q9 shorted b. Q8 shorted c. R44 open
2	-S	18	+1 vdc or more negative	R36 open
			+1 vdc or more positive	a. C6, C7 shorted b. Q6, Q7 shorted c. R12 open
3	-S	A2	0 vdc or more negative	a. Q1A shorted b. Q1B open
			0 vdc or more positive	a. C1 or C2 shorted b. Q3 shorted c. R14 or R7 open

TABLE 5-5. COMMON TROUBLES

Symptom	Checks and Probable Causes
High ripple	a. Check to see if output is grounded. Use 1μf capacitor if it is impossible to ground dc. b. Check collector to emitter voltage of Q10. Under full load conditions, it should be at least 1.5 vdc. Check voltage across CR17, CR18, CR19, Q11, and for low voltage across C18. c. Under loaded conditions, check to see if supply is operating in constant current.
Poor line regulation	Check reference regulator (para. 5-49).
Poor load regulation (constant current)	a. Check to see if C22, C23, C24, or CR33 is leaky. b. Reference circuit load regulation (para. 5-74 or 5-76 as applicable). c. Check clamp circuit Q3, CR3, CR4. d. Check for shunt load across the output terminals (such as a low impedance voltmeter). e. Operating in constant voltage at high output voltages.
Poor load regulation (constant voltage)	a. Poor measurement technique (para. 5-3). b. Reference circuit load regulation (para. 5-74 or 5-76). c. Check to see if supply is going into current limit.

TABLE 5-5. COMMON TROUBLES (cont.)

Symptom	Checks and Probable Causes
Poor stability (constant voltage)	a. Check stability of -6.2 volt reference. b. Noisy programming resistor, (R11). c. CR1, CR2, CR3 leaky. d. R1, R14, R15 noisy or drifting. e. Q1 defective.
Poor stability (constant current)	a. Check stability of +6.2 volt reference. b. Noisy programming resistor (R28). c. CR5, CR33, C22, C23, C24 leaky. d. R21, R30, R31, R20, R18 noisy or drifting. e. Q4 defective.
Oscillates (constant voltage)	Check adjustment of R35; C7 open.
Oscillates (constant current)	Check R34, C6; R27, C5.
Current limited (constant voltage)	Check voltage across Q10. Should be greater than 1.0 vdc. If less, check voltage across CR17, CR18, CR19, Q11, and for low voltage across C18.
Minimum output voltage 0.5 vdc	a. Q11 leaky. b. Q13, Q14 open.

TABLE 5-6. CHECKS AND ADJUSTMENTS
AFTER REPLACEMENT OF SEMICONDUCTOR DEVICES

Reference	Function	Check	Adjust
Q1	Constant voltage input circuit	Constant voltage line and load regulation	R6
Q7	Constant voltage gate-amplifier	Constant voltage load regulation and transient response	R35
Q8, 9, 10	Series regulator	Constant voltage load regulation	R6
Q4	Constant current input circuit	Constant current line regulation	---
Q6	Constant current gate-amplifier	Constant current line regulation	R34
Q3, 4	Clamp circuit	Constant current load regulation	---
Q13, 14	Reference circuit amplifier	Line Regulation	R55
CR1, 2, 5	Protection diode	Constant voltage load regulation	---
CR3	Protection diode	Constant current load regulation	---
CR30, 31	Rectifier diode	Voltage across C17	---
CR32, 33	Protection diode	---	---
CR7, 8, 9, 10 13, 14, 15, 17 18, 19, 27	Forward bias regulators	Voltage across each diode (0.6 to 0.85 volts)	---
CR24, 25, 28 29	Rectifier diodes	Voltage across C16 and C18	---
VR1	Positive reference voltage (+6.2 vdc)	Line and load regulation of +6.2 vdc	R55
VR2	Negative reference voltage (-6.2 vdc)	Line and load regulation of -6.2 vdc	R55

TABLE 5-7. ADJUSTMENT AND CALIBRATION SUMMARY

Adjustment or Calibration	Paragraph Reference	Control Device
Meter Zero	5-58	Meter Spring
Voltmeter Tracking	5-60	R59
Ammeter Tracking	5-62	R61
Zero Voltage Output	5-64	R5
Constant Voltage Programming Current	5-66	R15
Zero Current Output	5-68	R25
Constant Current Programming Current	5-70	R31
Output Voltage Line Regulation	5-72	R55
-6.2 Volt Reference Load Regulation	5-74	Replace VR2
+6.2 Volt Reference Load Regulation	5-76	Replace VR1
Transient Response	5-78	R35
Constant Voltage Load Regulation	5-80	R6

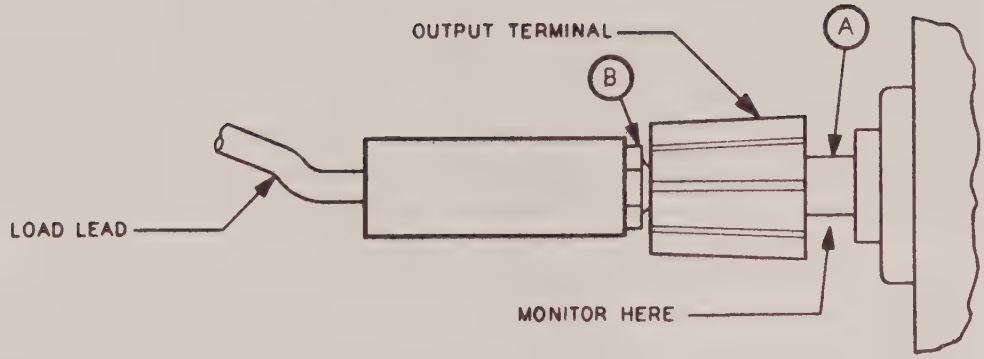


Figure 5-2. Front Terminal Measurement Technique

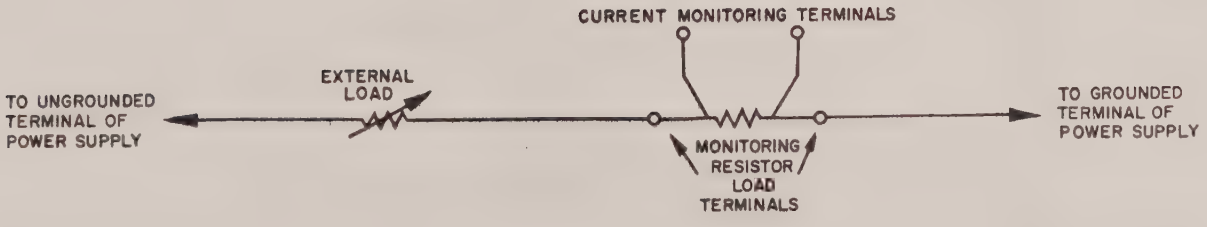

CURRENT MONITORING TERMINALS
EXTERNAL LOAD
TO UNGROUNDED TERMINAL OF POWER SUPPLY
TO GROUNDED TERMINAL OF POWER SUPPLY
MONITORING RESISTOR LOAD TERMINALS

Figure 5-3. Output Current Measurement Technique

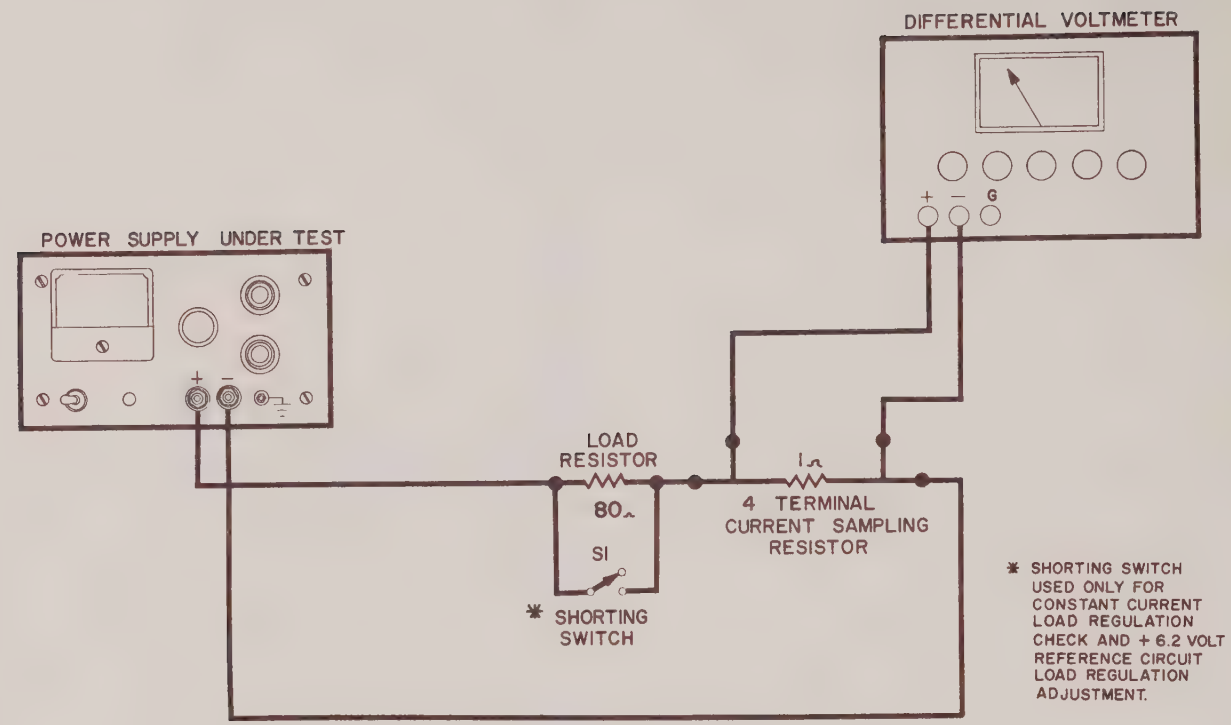

DIFFERENTIAL VOLTMETER
+ − G
POWER SUPPLY UNDER TEST
+ −
LOAD RESISTOR
80Ω
SI
* SHORTING SWITCH
1Ω
4 TERMINAL CURRENT SAMPLING RESISTOR
* SHORTING SWITCH USED ONLY FOR CONSTANT CURRENT LOAD REGULATION CHECK AND + 6.2 VOLT REFERENCE CIRCUIT LOAD REGULATION ADJUSTMENT.

FIG. 5-4
CONSTANT CURRENT, TEST SETUP

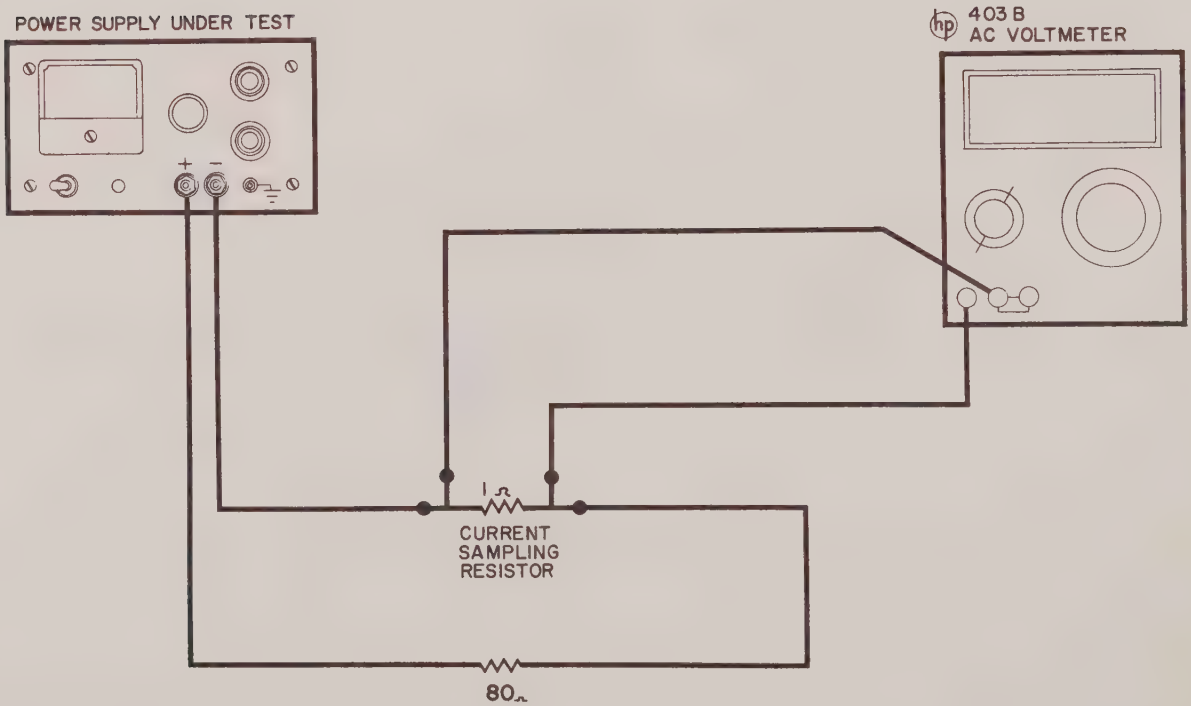


FIG. 5-5
CONSTANT CURRENT RIPPLE AND NOISE,
TEST SETUP

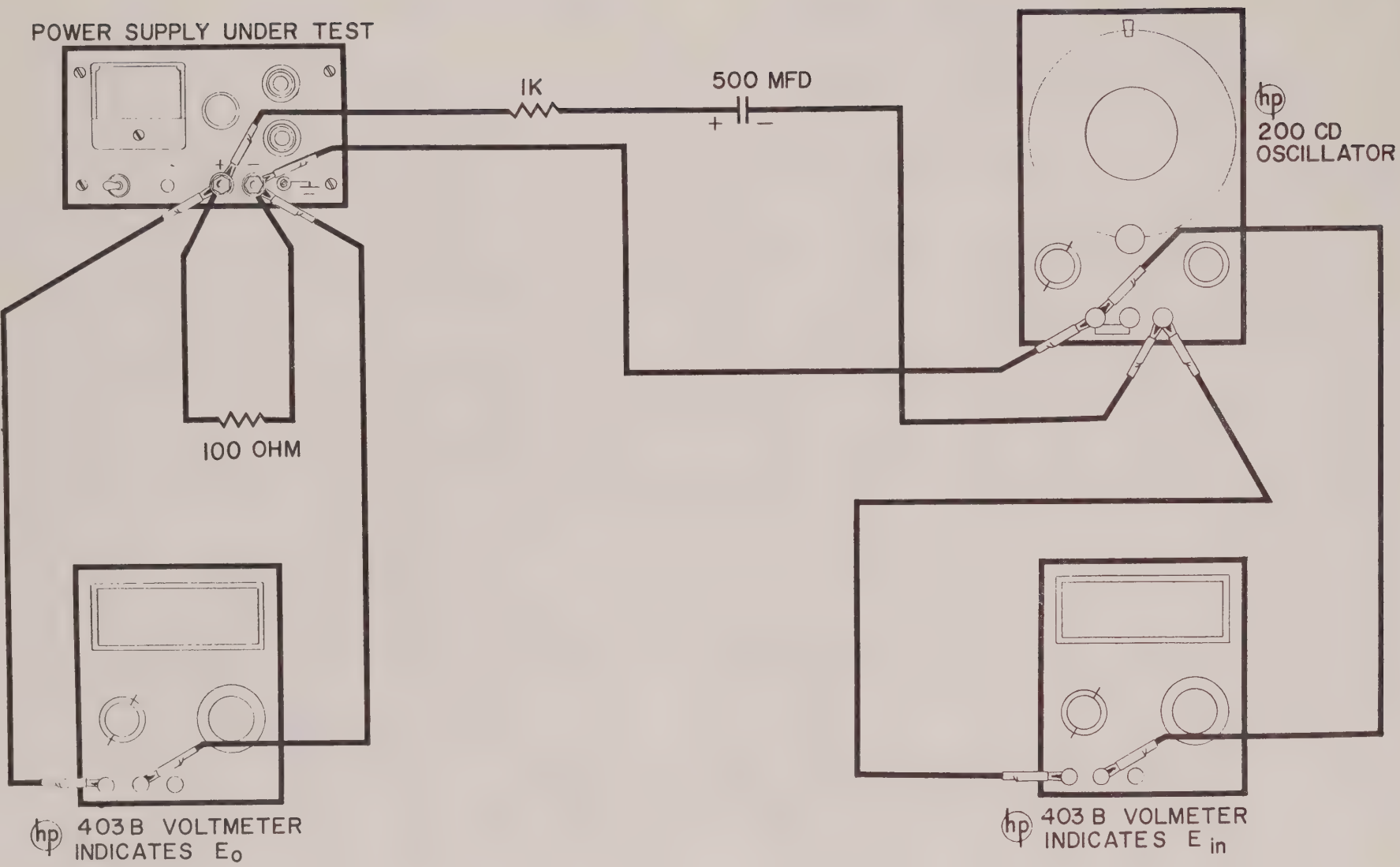


FIG. 5-6
OUTPUT IMPEDANCE, TEST SETUP

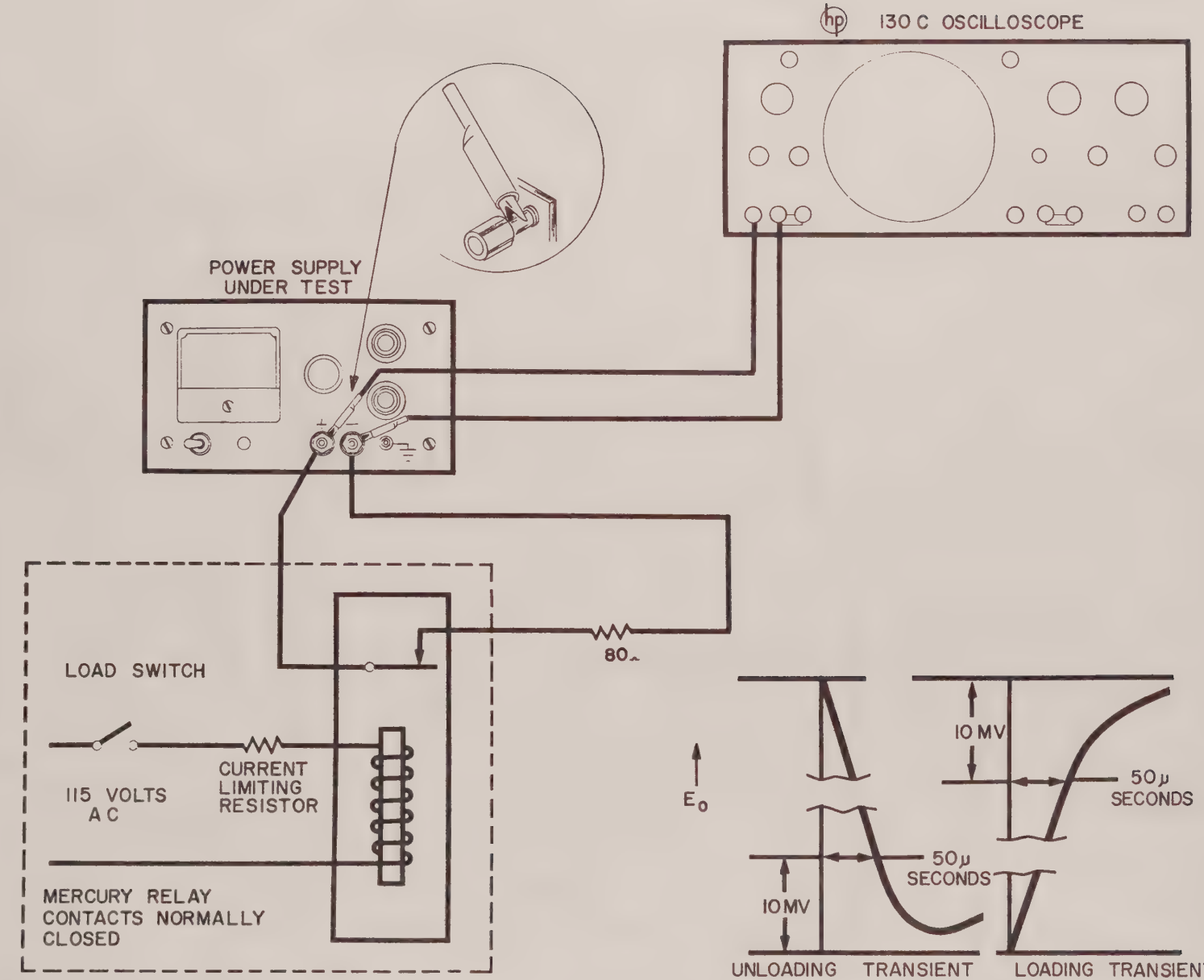


FIG. 5-7
TRANSIENT RECOVERY TIME, TEST SETUP

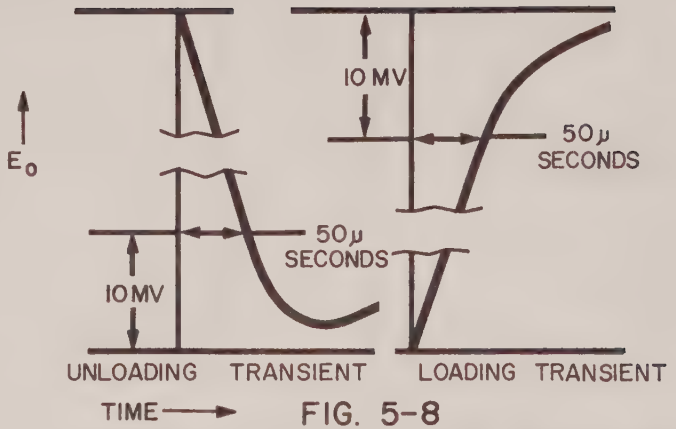


FIG. 5-8
TRANSIENT RECOVERY TIME WAVEFORM

SERVICING ETCHED CIRCUIT BOARDS

Excessive heat or pressure can lift the copper strip from the board. Avoid damage by using a low power soldering iron (50 watts maximum) and following these instructions. Copper that lifts off the board should be cemented in place with a quick drying acetate base cement having good electrical insulating properties.

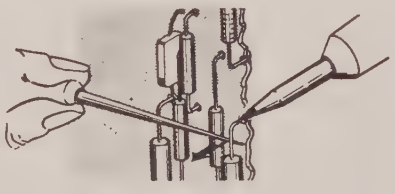
A break in the copper should be repaired by soldering a short length of tinned copper wire across the break.

Use only high quality rosin core solder when repairing etched circuit boards. NEVER USE PASTE FLUX. After soldering, clean off any excess flux and coat the repaired area with a high quality electrical varnish or lacquer.

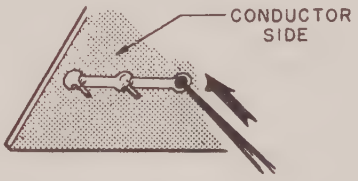
When replacing components with multiple mounting pins such as tube sockets, electrolytic capacitors, and potentiometers, it will be necessary to lift each pin slightly, working around the components several times until it is free.

WARNING: If the specific instructions outlined in the steps below regarding etched circuit boards without eyelets are not followed, extensive damage to the etched circuit board will result.

1. Apply heat sparingly to lead of component to be replaced. If lead of component passes through an eyelet in the circuit board, apply heat on component side of board. If lead of component does not pass through an eyelet, apply heat to conductor side of board.

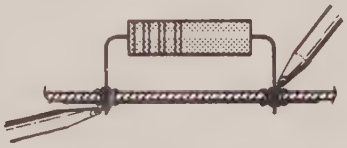


2. Reheat solder in vacant eyelet and quickly insert a small awl to clean inside of hole. If hole does not have an eyelet, insert awl or a #57 drill from conductor side of board.



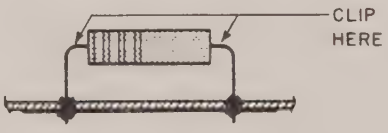
3. Bend clean tinned leads on new part and carefully insert through eyelets or holes in board.

4. Hold part against board (avoid overheating) and solder leads. Apply heat to component leads on correct side of board as explained in step 1.

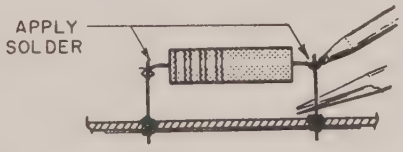


In the event that either the circuit board has been damaged or the conventional method is impractical, use method shown below. This is especially applicable for circuit boards without eyelets.

1. Clip lead as shown below.



2. Bend protruding leads upward. Bend lead of new component around protruding lead. Apply solder using a pair of long nose pliers as a heat sink.



This procedure is used in the field only as an alternate means of repair. It is not used within the factory.

Figure 5-9. Servicing Etched Circuit Boards

SECTION VI
REPLACEABLE PARTS

6-1 INTRODUCTION

6-2 This section contains information for ordering replacement parts.

6-3 Table 6-1 lists parts in the alpha-numerical order of the circuit designators and provides the following information:

A. Description (See list of abbreviations below).
B. Total quantity used in the instrument.
C. Manufacturer's part number.
D. Manufacturer.
E. The Manufacturer's code number as listed in the Federal Supply Code for Manufacturers H4-1.
F. The H-P Part Number.
G. The recommended spare parts quantity for complete maintenance during one year of isolated service. (Column A).

6-4 ORDERING INFORMATION

6-5 To order replacement parts, address order or inquiry either to your authorized Harrison Laboratories sales representative or to Customer Service, Harrison Laboratories, 100 Locust Avenue, Berkeley Heights, New Jersey.

6-6 Specify the following information for each part:

A. Model and complete serial number of instrument.
B. Circuit reference designator.
C. Description.

6-7 To order a part not listed in Table 6-1, give a complete description of the part and include its function and location.

Reference Designators

A	= assembly	K	= relay	T	= transformer
B	= motor	L	= inductor	V	= vacuum tube, neon bulb, photocell, etc.
C	= capacitor	M	= meter		
CR	= diode	P	= plug	X	= socket
DS	= device signaling (lamp)	Q	= transistor	XF	= fuseholder
E	= misc. electronic part	R	= resistor	XDS	= lampholder
F	= fuse	RT	= thermistor	Z	= network
J	= jack	S	= switch		

ABBREVIATIONS

a	= amperes
c	= carbon
cer	= ceramic
coef	= coefficient
com	= common
comp	= composition
conn	= connection
crt	= cathode-ray tube
dep	= deposited
elect	= electrolytic
encap	= encapsulated
f	= farads
fxd	= fixed
GE	= germanium
grd	= ground (ed)
h	= henries
Hg	= mercury
impg	= impregnated
ins	= insulation (ed)
lin	= linear taper
log	= logarithmic taper
m	= milli = 10^{-3}
M	= megohms
ma	= milliamperes
μ	= micro = 10^{-6}
mfr	= manufacturer
mtg	= mounting
my	= mylar
NC	= normally closed
Ne	= neon
NO	= normally open
nsr	= not separately replaceable
K	= kilo = 1000
obd	= order by description
p	= peak
pc	= printed circuit board
pf	= picofarads = 10^{-12} farads
pp	= peak-to-peak
ppm	= parts per million
pos	= position (s)
poly	= polystyrene
pot	= potentiometer
prv	= peak reverse voltage
rect	= rectifier
rot	= rotary
rms	= root-mean-square
s-b	= slow-blow
sect	= section (s)
Si	= silicon
sil	= silver
sl	= slide
td	= time delay
TiO_2	= titanium dioxide
tog	= toggle
tol	= tolerance
trim	= trimmer
twt	= traveling wave tube
var	= variable
w/	= with
W	= watts
ww	= wirewound
w/o	= without
cmo	= cabinet mount only

MANUFACTURERS

AB	Allen-Bradley
B	Bendix Corporation
Beede	Beede Elec. Instr. Co.,Inc.
Buss	Bussman Mfg. Company
Carling	Carling Electric Company
CTS	CTS Corporation
Elco	Elco Corporation
GE	General Electric Company
GI	General Instrument Company
HH	Hardwick-Hindle Company
Hoff	Hoffman Electric Company
Kulka	Kulka Electric
Mot	Motorola, Inc.
RCA	Radio Corporation of America
Reliance Mica	Reliance Mica Corporation
Semcor	Semcor Corporation
Sloan	Sloan Company
Sprague	Sprague Electric
Superior	Superior Electric
Sylv	Sylvania Electric
TI	Texas Instruments
WL	Ward Leonard Electric

Circuit Reference Number	Description	Quantity	Mfg. Part # or type	Mfg.	Mfg. Code*	HP Stock #	A
C1,5	fxd, elect. 1µf 50VDC	2	D27975	Sprague	56239		4
C2,7	fxd, film 0.0047 µf 200 VDC	2	192P47292	Sprague	56289	0160-0157	4
C3,6	fxd, film 0.0022 µf 200 VDC	2	192P22292	Sprague	56289	0160-0154	4
C4	fxd, elect. 4.7 µf 35 VDC	1	150D475X9 03502	Sprague	56289	0180-0100	4
C8,9,13,14	Not Assigned	-	-	-	-		-
C10	fxd, film 0.001 µf 200 VDC	1	192P10292	Sprague	56289	0160-0153	2
C11	fxd, elect. 10µf 100VDC	1	30D106G 100DD4	Sprague	56289	0180-0091	2
C12	fxd, elect. 20µf 15VDC	1	30D206G 015BB4	Sprague	56289		2
C15,22	fxd, elect. 5µf 65 VDC	2	D33689	Sprague	56289		4
C16	fxd, elect. 325µf 35VDC	1	D34656	Sprague	56289		2
C17	fxd, elect. 100µf 65VDC	1	D70704	Sprague	56289		2
C18	fxd, elect. 750µf 75VDC	1	D38812	Sprague	56289	0180-1891	2
C19,20,21	fxd, cer 0.05µf 500VDC	3	33C58	Sprague	56289		6
C23	fxd, elect. 490µf 75VDC	1	D38618	Sprague	56289		2
C24	fxd, elect. 4.7µf 50VDC	1	150D475X0 050B2	Sprague	56289		2
CR1,2,3,4,5	Diode, Sil	5	1N485B	Sylv.	93332	1901-0033	10
CR6,11,16,23,26	Not Assigned	-	-	-	-	-	-
CR7,8,9,10,13,14,15 17,18,19,27	Rect. Sil 200MA 10PRV	11	111S1	Sylv.	93332		22
CR12,24,25,28,29,30 31,32,33	Rect. Sil 500MA 200PRV	9	1N3253	RCA	02737	1901-0026	18
CR20,21,22	Not Used	-	-	-	-		-
DS1	Indicator Light, Neon	1	1B2	Eldema	03797		2
F1	Fuse Cartridge, 2A @ 250V	1	312002	Littlefuse	75915		3
Q1,4	SS, NPN, Diff Amp Sil	2	4JX12A839	GE	03504		4

Circuit Reference Number	Description	Quantity	Mfg. Part # or type	Mfg.	Mfg. Code*	HP Stock #	A
Q2, 5	Not Assigned	-	-	-	-	-	-
Q3, 8, 13	SS, NPN, Sil	3	4JX16B533	GE	03508		6
Q6, 7	SS, PNP, Ger.	2	GT2555	TI	11711		4
Q9	Power NPN Sil	1	B3232	Bendix	83298		2
Q10	Power PNP Ger	1	2N2147	RCA	02735		2
Q11	Power PNP Ger	1	B1203	Bendix	83298		2
Q12	Not Used	-	-	-	-		-
Q14	SS, PNP, Ger	1	2N1379	TI	01295		2
R1, 21	fxd, WW 470 ohms ±5%	2	Type BWH	IRC	07716		4
R2, 22	fxd, comp 6.2K ohms ±5% 1/2W	2	EB6226	AB	01121	0686-6225	-
R3	fxd, comp 3.6K ohms ±5% 1/2W	1	EB3625	AB	01121	0686-3625	-
R4, 23, 24	fxd, comp 3.9K ohms ±5% 1/2W	3	EB3925	AB	01121	0686-3925	-
R5	fxd, comp 470K ohms ±5% 1/2W	1	EB4745	AB	01121	0686-4745	-
R6	Var. WW 3K ohms	1	110-F4	CTS	11236		2
R7	fxd, comp 62K ohms ±5% 1/2W	1	EB6235	AB	01121	0686-6235	-
R8	fxd, comp 22K ohms ±5% 1/2W	1	EB2235	AB	01121	0686-2235	-
R9	fxd, comp 33K ohms ±5% 1/2W	1	EB3335	AB	01121	0686-3335	-
R10	fxd, comp 10 ohms ±5% 1/2W	1	EB1005	AB	01121	0686-1005	-
R11	Var. WW Dual 25K/200 ohms	1	Type 100149-7	H-Lab	09182		2
R12	fxd, film 43Kohms ±1% 1/8W	1	MF5C-D 43K-F	Electra	19701		2
R13	fxd, film 100K ±1% 1/8W	1	MF5C-D 100K-F	Electra	19701	0757-0465	2
R14	fxd, WW 3.3K ohms ±5% 20ppm 3W	1	242E3325	Sprague	56289		2
R15, 31	fxd, comp Selected ±5% 1/2W	2	-	AB	01121		-
R16, 17, 29, 46, 47	Not assigned	-	-	-	-		-
R18	fxd, comp 3.3 ohms ±5% 1/2W	1	EB0335	AB	01121	0686-0335	-
R19	fxd, comp 91K ohms ±5% 1/2W	1	EB9135	AB	01121	0686-9135	-
R20	fxd, WW 3 ohms ±5% 10W	1	Type 10XM	WL	63743		2
R25	fxd, film 221K ohms ±1% 1/8W	1	MF5C-D 221K-F	Electra	19701	0757-0473	2
R26	fxd, film 1.5K ohms ±1% 1/8W	1	MF5C-D 1.5K-F	Electra	19701	0757-0427	2

Circuit Reference Number	Description	Quantity	Mfg. Part # or type	Mfg.	Mfg. Code*	HP Stock #	A
R27	fxd, comp 39 ohms ±5% 1/2W	1	EB3905	AB	01121	0686-3905	-
R28	Var. WW Dual 1.8K/20 ohms	1	Type 100149-2	H-Lab	09182	2100-0995	2
R30	fxd, WW 6.5K ohms ±5% 3W 20ppm	1	242E6225	Sprague	56289		2
R32	fxd, comp 390 ohms ±5% 1/2W	1	EB3915	AB	01121	0686-3915	-
R33,50	fxd, comp 12K ohms ±5% 1/2W	2	EB1235	AB	01121	0686-1235	-
R34,39	fxd, comp 200 ohms ±5% 1/2W	2	EB2015	AB	01121	0686-2015	-
R35	Var. WW 1K ohm Modify	1	110-F4	CTS	11236		2
R36	fxd, comp 220 ohms ±5% 1/2W	1	EB2215	AB	01121	0686-2215	-
R37,56	fxd, comp 470 ohms ±5% 1/2W	2	EB4715	AB	01121	0686-4715	-
R38	fxd, comp 300 ohms ±5% 1/2W	1	EB3015	AB	01121	0686-3015	-
R40	Not Used	-	-	-	-		-
R41	fxd, WW 500 ohms ±5% 5W	1	Type 5XM	WL	63743		2
R42	fxd, WW 100 ohms ±5% 65W	1	Type 817	WL	63743		2
R43	fxd, comp 4.3K ohms ±5% 1/2W	1	EB4325	AB	01121	0686-4325	-
R44	fxd, comp 43K ohms ±5% 1/2W	1	EB4335	AB	01121	0686-4335	-
R45	fxd, comp 82 ohms ±5% 1/2W	1	EB8205	AB	01121	0686-8205	-
R48	fxd, WW 1K ohm ±5% 10W	1	Type 10XM	WL	63743		2
R49	fxd, comp 1.6K ohms ±5% 1/2W	1	EB1625	AB	01121	0686-1625	-
R51	fxd, film 6.2K ohms ±1% 1/8W	1	MF5C-D 6.2K-F	Electra	19701		2
R52	fxd, film 619 ohms ±1% 1/4W	1	MF6C-D 619-F	Electra	19701	0757-0728	2
R53	fxd, comp 47K ohms ±5% 1/2W	1	EB4735	AB	01121	0686-4735	-
R54	fxd, comp 8.2K ±5% 1/2W	1	EB8225	AB	01121	0686-8225	-
R55,63	fxd, comp 51K ohms ±5% 1/2W	2	EB5135	AB	01121	0686-5135	-
R57	fxd, comp 82K ohms ±5% 1/2W	1	EB8235	AB	01121	0686-8235	-
R58	fxd, comp 560 ohms ±5% 1/2W	1	EB5615	AB	01121	0686-5615	-
R59,61	Var. WW 250 ohms	2	110-F4	CTS	11236		4
R60	fxd, comp 510 ohms ±5% 1/2W	1	EB5115	AB	01121	0686-5115	-
R62	fxd, WW 0.51 ohms ±5%	1	Type BWH	IRC	07716		2
S1	on/off switch	1	T110	Carling	73559		2
S2	Meter switch, Wafer	1	865BS2	H-Lab	09182		2

Circuit Reference Number	Description	Quantity	Mfg. Part # or type	Mfg.	Mfg. Code*	HP Stock #	A
T1	Pwr Transformer (110/220V)	1	H397	H-Lab	09182		2
VR1,2	Diode, Zener 6.2V	2	1N821	N.A.Elect.	06486	1902-0761	4
	Barrier Strip	1	600-YSY-13	Kulka	75382		2
	Line Cord	1	KH-4629	Beldon	70903		2
	18-3 (16-30) Stranded Plug PH151 Type SJT Jacket Strip 2" Strip Conductor 1/2 Tin						
	Strain Relief Bush.	1	SR-6P-1	Heyco	28520		2
	Fuse Holder	1	342014	Littlefuse	75915	1400-0048	2
	Binding Post Br.Ni.Pl.	2	137	HH Smith	83330		1
	5-Way Binding Post (Red)	1	DF30RC	Superior	58474		2
	5-Way Binding Post (Black)	1	DF30BC	Superior	58474		2
	Meter Panel, 200 μa F.S. Internal Resistance 1000 ohms Knife Edge DDual Scale 0-40V 0-600ma	1	H649	H-Lab	09182		2
	Knob 1/4 Shaft	1	S-647-3L-BB	Kurz-Kasch	75376		1
	Knob 3/16 Shaft	2	S-645-5L BB-538	Kurz-Kasch	75376		2
	Knob 17/64	2	S-656-3L BB-549	Kurz-Kasch	75376		2
	Transistor Socket	3	3305	Elco	91662		3
	Mica Insul. Washer	2	734	Reliance	08532		4
	Bushings Teflon	4	100146-1	H-Lab	09182		4
	Bushings Teflon	4	100151-1	H-Lab	09182		4
	Tinnerman Nut	10	C11228-632-4	Tinnerman	89032		10
	Rubber Bumpers	4	F7254A	Bud	71218		4

A Recommended spares for one year for 10 units

* As listed in Federal Supply Code for Manufacturers H4-1 (March 1963).

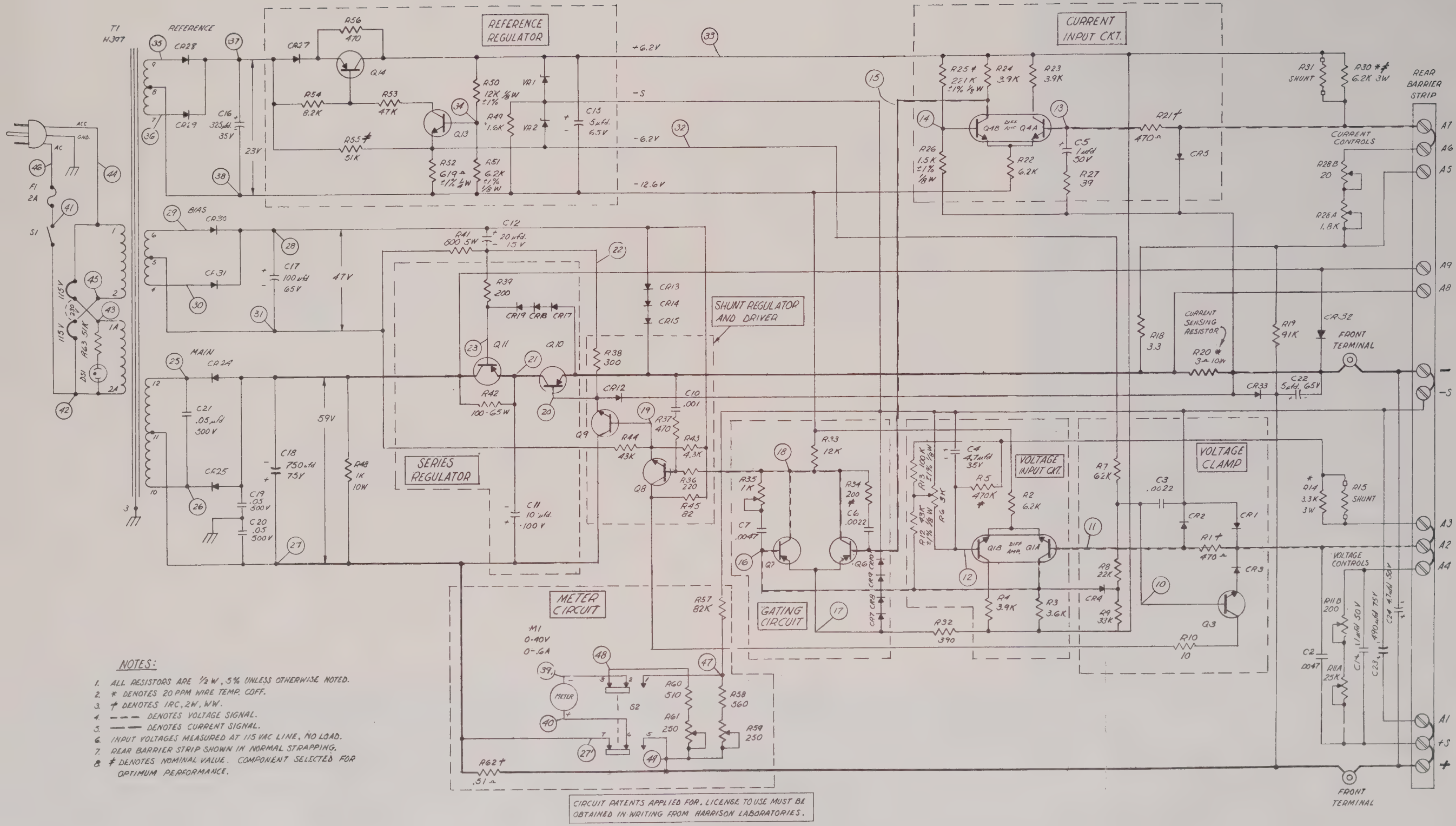


Figure 4-2. Schematic Diagram

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